COLORADO CANYON

A NATURAL AREA SURVEY
NO. 11

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976

The full-color frontispiece is by photographer Reagan Bradshaw and represents but a small part of the work he recorded in the course of the Colorado Canyon area survey. Transparencies of his photos of this and other survey areas have been filed with the Natural Areas Survey project, Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin. Mr. Bradshaw is one of the finest nature photographers of the Southwest. His work on these natural areas is sure to increase public awareness of the need to save and protect.

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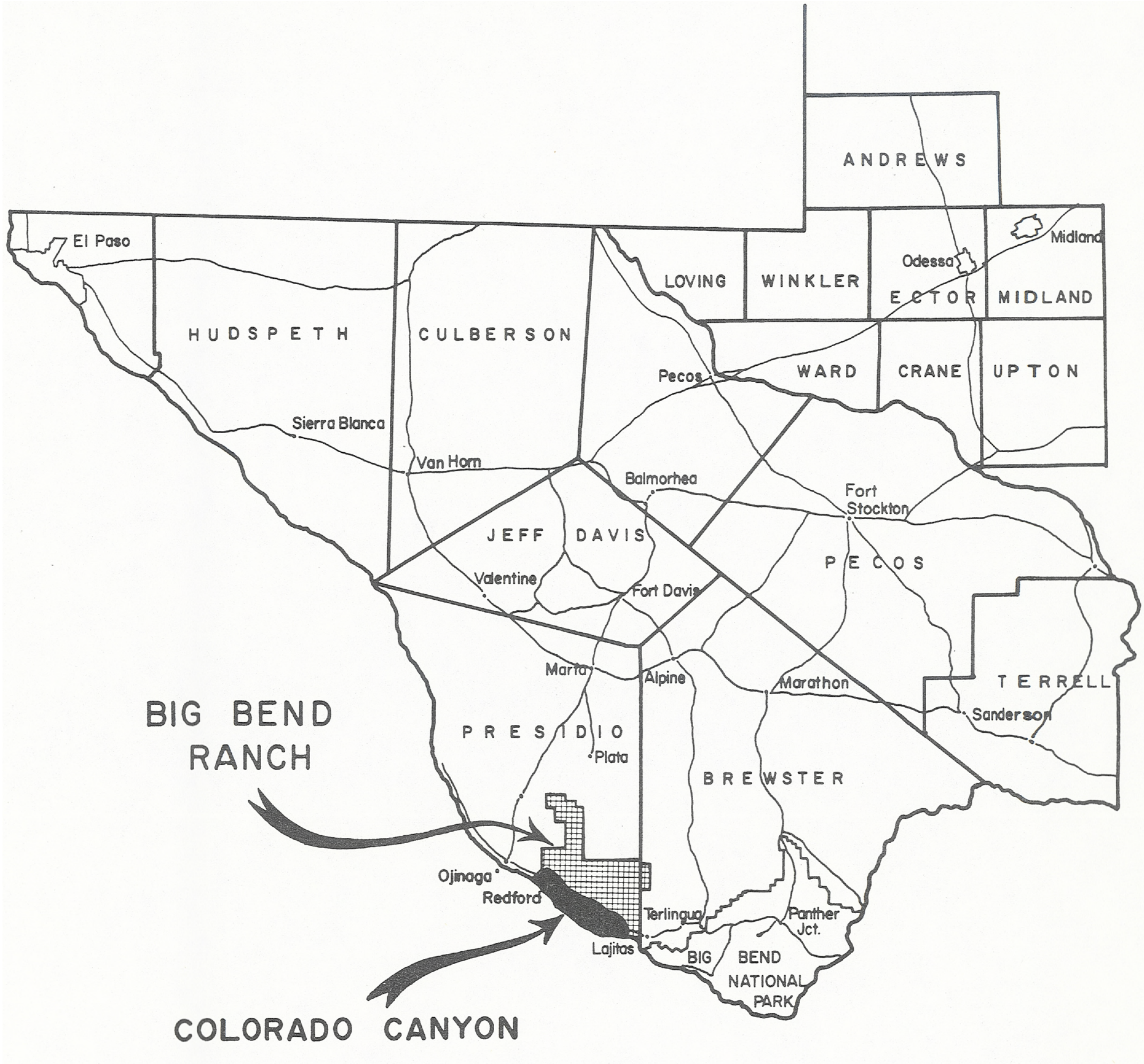

ANDREWS
El Paso
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UPTON
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Van Horn
Balmorhea
Fort Stockton
JEFF DAVIS
PECOS
Valentine
Fort Davis
Marfa
Alpine
Marathon
TERRELL
Sanderson
BIG BEND RANCH
PRESIDIO
Plata
BREWSTER
Ojinaga
Redford
Terlingua
Panther Jct.
Lajitas
BIG BEND NATIONAL PARK
COLORADO CANYON

THE UNIVERSITY OF TEXAS AT AUSTIN
LYNDON B. JOHNSON SCHOOL OF PUBLIC AFFAIRS
AUSTIN, TEXAS 78712

Texas Parks and Wildlife Commission
Pearce Johnson, Chairman
4200 Smith School Road
Austin, Texas 78744

Dear Mr. Chairman:

The Lyndon B. Johnson School of Public Affairs of The University of Texas at Austin respectfully submits herewith its report, Colorado Canyon: A Natural Area Survey, pursuant to the joint request of the Texas Historical Commission, the General Land Office, and the Texas Parks and Wildlife Department, and in fulfillment of Inter-agency Contract (74-75) 1168.

The Colorado Canyon, like each of the other areas undertaken at your request, was scientifically and historically surveyed, mapped, and photographed, which involved the recruitment and direction of a field team of geologists, archeologists, botanists, zoologists, paleoentomologists, ornithologists, cartographers, photographers, landmen, and historians.

Texas is a diverse and beautiful land with a rich heritage and abundant natural and scientific wonders that should be preserved for the wise use and enjoyment of ourselves and of generations to come. As your commission pointed out in requesting this survey, the more significant natural areas are disappearing all too rapidly in Texas. It is our hope that the data gathered here will be instrumental in reversing that trend.

Sincerely,

Don Kennard

Don Kennard
Director
Natural Areas Survey

FOREWORD

The Natural Areas Survey project of the Lyndon B. Johnson School of Public Affairs at The University of Texas presents this study of Colorado Canyon, a unique Texas natural feature. This report is respectfully submitted to the Governor, the Texas Legislature, and the Texas Parks and Wildlife Commission in order that they be more fully informed about the resources of the state.

All studies in this series were prepared by multidisciplinary teams representing the natural and social sciences. Each study presents a comprehensive survey of the plants, animals, and geology of the area, as well as a review of its importance to man, both ancient and modern. The sites were chosen to fall within the definition of natural areas used in the Texas Outdoor Recreation Plan (Texas Parks and Wildlife Department 1975), "natural areas are areas or sites, which, because of their scenic beauty, rarity, recreation value, uniqueness, ecological importance, or cultural value should be protected for posterity."

There are perhaps a few hundred natural areas remaining in Texas, ranging from sections of mountainous land to half-acre sloughs. They can be found among our mountains, plains, shores, and woodlands. Together they could form a network of wildlife sanctuaries and study areas. It is our hope that citizens and state officials will commit themselves to the cause that these areas be preserved as remnants of the natural world and as sanctuaries for the rare and fragile living things which are succumbing to man's increase on this globe. If these areas are overtaken by development, these studies will provide a bare record of the beauty and scientific wonder which was lost.

With the release of this and the companion reports of this year, the list of project areas now stands at thirteen. Other reports in the series are:

Capote Falls
Matagorda Island
Mount Livermore and Sawtooth Mountain
(and supplement)
Victorio Canyon
Blue Elbow Swamp
Devils River
Canadian Breaks
Devil's Sinkhole Area—
Headwaters of the Nueces River
The Solitario
Fresno Canyon
Bofecillos Mountains
Falcon Dam-Thorn Woodland

ACKNOWLEDGEMENTS

Material for this and the four other reports in this series was assembled and edited by Don Kennard. Editorial contributions to the final manuscripts were made by Griffin Smith, Jr., Senior Editor of *Texas Monthly* magazine, Truett Latimer, Executive Director, Texas Historical Commission, Dr. Marshall Johnston, Professor of Botany, The University of Texas at Austin, Curtis Tunnell, State Archeologist, and Edgar B. Kincaid, Jr.

Color frontispiece was by Reagan Bradshaw. Erlene and Linda Hill were responsible for typography and prepared the layout with the help of B. J. Hill. We are indebted to Dr. Keith Arnold, Dr. Stephen Spurr and Ross Shipman of the Division of Natural Resources and Environment, to the Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, and to Ronnie Fiesler, Barbara Walker, and John McCully of our staff for their assistance in handling the multitude of details and arrangements necessary to produce these reports.

We are especially indebted to Exxon Co. USA whose interest, encouragement, and generous grant of funds made possible the publication of these reports and significantly enhanced the field research effort of this and other projects undertaken by the Survey.

It is difficult to acknowledge, without omission, the time and effort unselfishly given by so many friends of Texas's natural heritage. With a fear that we may have inadvertently missed others, we wish to give special thanks to:

Robert O. Anderson, Robert B. Anderson, Joe Mims, and Ralph Hager of the Diamond A Cattle Company and the Big Bend Ranch

Bob Armstrong, Commissioner of the General Land Office

Jack Burns, Alpine, Texas

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Texas Historical Commission and its staff

Chairman Pearce Johnson and the members of the Texas Parks and Wildlife Commission

Raul and Enrique Madrid of Redford, Texas

Dr. Hugh Meredith, President, and Dr. Mike Powell, Sul Ross State University

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Red Oliver, Steve Kennedy and Mike McKann, General Land Office

George Pool, U.S. Public Health Service, El Paso, Texas

Linda Roark, Terlingua, Texas

Anders Saustrup and the staff of the University of Texas Rare Plant Study Center

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IMPRESSIONS OF COLORADO CANYON

Griffin Smith, jr.

Colorado Canyon is the first, and shortest, of the Big Bend's monumental canyons. Its entrance 28 miles southeast of Presidio brings to a close the broadly majestic, even extravagant, valley through which the river has passed for most of its length below El Paso. Beginning at Colorado Canyon the Rio Grande struggles to find a path to the sea.

Eons ago, the volcanic rock at its entrance was a natural dam holding back a vast lake within the Presidio and Redford Bolsons. Sediments carried by rainfall runoff in the ancestral Rio Conchos and by snowmelt in the ancestral Rio Grande gradually filled the basin until the dam was breached. With excruciating slowness, the waters began to etch a downstream path, excavating canyons that have steadily deepened over time and surrounded the river with a scenic badlands of eroding tributaries.

The barrier broken by the river proved more difficult for man to overcome. Colorado Canyon, together with a formidable dome of rhyolite porphyry two miles downstream known as Big Hill, impeded human traffic across this region from prehistoric times until a road was blasted through in 1961. Archaeological evidence shows that the settlements of Indians who practiced agriculture and manufactured pottery throughout much of the American southwest cease abruptly near Redford; not a single ceramic sherd has been discovered around Colorado Canyon or beyond. Similarly, the area's lithic artifacts do not correspond to types associated with the Big Bend, the Davis Mountains, or any downstream culture, prompting archaeologists to speculate that whatever primitive peoples lived here were an isolated society confined to the Colorado Canyon-Fresno Canyon vicinity.

Presidio is of course rich in both Spanish and nineteenth century American history; but its commerce flowed along a north-south line through the interior, avoiding the river and Colorado Canyon. By following a passable route through Alamito Creek, the Chihuahua Trail linked Presidio far more closely with northern Mexico and the American midwest than with the rest of Texas. Efforts to find a safe passage from San Antonio through Presidio to El Paso came to grief in the Hays-Highsmith expedition of 1848 and the Whiting expedition of 1849. Not until after the Civil War was the connection made, and even then it crossed overland, far from the river.

The spectacular entrance to Colorado Canyon was viewed as the gateway to an unknown region—on those rare occasions when it was viewed at all—as late as 1852, when Major William Emory's scientific reconnaissance party passed through. His was the first serious attempt to chart the hidden reaches of the river, if one discounts the ludicrous Love expedition of 1850, which tried to reach El Paso from Rio Grande City in 50-foot flatbottomed boats, and the saner Smith expedition, which managed to navigate upstream to a point eighty miles above the confluence of the Pecos. The work begun by Emory was not resumed until 1899, when geologist Robert Hill, with far greater expertise, mapped the entire river system from Presidio to Langtry. In the interim and until quite recent times, man was a stranger to the swirling water and the sunsets refracted beneath the craggy walls; Colorado Canyon slept the deep primeval sleep of wilderness unobserved.

Today it is easily negotiable by canoe or kayak, especially during the spring or fall when water levels are most likely to be favorable. Access is almost effortless; *Camino del Rio* links the two points with a ten-minute drive, and the land (still private) slopes gently to the river. Between these points the road veers out of sight behind high hills, allowing the lucky canoeist total solitude for the duration of his run. Few wild rivers anywhere are so well-adapted to satisfy an intruder's every wish.

At normal water the trip takes half a day. Enough rapids exist to keep the adventure lively, but the canoeist can still find time to admire the geologic drama unfolding around him. Through immense faulted blocks of volcanic lava, tuffs, and ash the Rio Grande cuts, rolling past massive columnar jointed cliffs of weathered orange ignimbrite. In the deepest part of the canyon, the walls rise 800 feet above the water's edge.

A narrow, steep side canyon enters from the left. This is Closed Canyon, a tributary carrying outwash from the Bofecillos Mountains. Often no more than a few yards wide it provides valuable shade in the heat of the day, creating a refuge. The Broad-tailed Hummingbird has been seen nesting here, as has the Prairie Falcon; and near its mouth the rare perennial *Machaeranthera gypsophila* displays its showy white-and-yellow flowers after a drenching rain.

The slender green band of vegetation along the river is dominated by plants foreign to the botany of the Chihuahuan Desert; Bermuda grass and salt cedar, both native to India; Cariyza, an Asian grass; and South American tree tobacco, beloved by the six species of hummingbirds known to visit here. But the sandy banks of Colorado Canyon also play host to such familiar domestic plants as mesquite, seep-willow, canyon grape, sunflower, and poison ivy.

With more justification than canoeists have, bats and birds use the river as a corridor through otherwise inhospitable terrain. Multitudes of migratory water-fowl pay annual vists; others arrive and depart with unpredictable irregularity. Birders' records are replete with more than 150 different species, and twice that many are thought to put in an appearance during any given year.

As the river emerges into lowlands between the canyon and Big Hill, startled canoeists have occasionally encountered equally startled bears, who turn tail and head back to the sanctuary of the Mexican mountains. Much more common, however, are the mysterious Mexican beavers, who do not build dams or lodges as good bourgeois beavers do, but who nevertheless often wreak havoc with their destructive gnawing of valuable shade trees. Muskrats are gradually returning to their former range along this portion of the river; several have been sighted upstream from Lajitas, and they may already have re-established themselves as far west as Big Hill. Three rare snakes—the Texas Lyre Snake, the Trans-Pecos Rat Snake, and the Gray-banded Kingsnake—are among the many species known to inhabit the Big Hill.

Construction of *Camino del Rio,* which made these canoe trips feasible, has paradoxically set in motion forces that could destroy Colorado Canyon's fragile ecology. Commercial animal dealers from as far away as California now flock to the highway to capture and eventually sell rare specimens of wildlife, particularly the Gray-banded Kingsnake, which fetches more than $100 in the pet trade. Fishermen have already introduced one foreign species to the river, the Barred Tiger Salamander; and they have been known to smash the dry mud nests of cliff swallows and use the baby birds as bait.

The greatest threat to Colorado Canyon's survival comes, however, from an altogether different source: the river itself. Even in Spanish days the Rio Grande above La Junta occasionally ran dry; modern dams have simply made an intermittent condition almost permanent. For decades, the Rio Conchos has supplied the flow that kept the "Rio Grande" below Presidio alive. The riparian existence of Colorado Canyon and the others in Big Bend—Santa Elena, Mariscal, Boquillas, the Lower Canyons—largely depends on the rains of the Sierra Madre Occidental, transported by the Conchos across the arid reaches of Northern Mexico. But dams built for irrigation in the mountains southwest of Chihuahua have increasingly begun to stanch that flow. Although a minimum supply of water is presently guaranteed by international treaty, the desperate agricultural needs of Mexico's burgeoning population may soon require all the water the Conchos can provide. Treaties have been known to yield to less. If the alternative is hunger, Colorado Canyon may be fated to become, before the end of this century, a dry arroyo evidencing the fitfulness of man's rapport with nature.

A BRIEF HISTORICAL SURVEY OF THE BIG BEND AREA

Bruce D. Saunders

Almost hidden in a remote corner of West Texas is a vast area of land that modern civilization has left virtually untouched for decades. The whole region of the Big Bend—bounded on the west and south by the Rio Grande, the Pecos River on the east, and the state of New Mexico on the north—has been a very difficult area to settle. Summer temperatures that can occasionally soar to 55° centigrade (130°F) during the day and then drop rapidly at night, a limited amount of annual rainfall, a scarcity of springs and waterholes, the presence of spectacular but treacherous mountain ranges, all have contributed to the region's lack of early settlers. It is a forbidding area that has attracted only the strongest and most determined individuals who must constantly battle the natural elements found there. Yet there is a beauty and grandeur to the open spaces of this region that the majestic mountain ranges and deep valleys accentuate. Man has been forced to wrestle the land away from the cactus, ocotillo, mountain lions, rattlesnakes, and scorpions that have successfully inhabited the land for centuries. Visitors find the area exhilarating and challenging and often succumb to what columnist and historian Frank Tolbert calls "Big Bend Fever." Walter P. Webb, the noted historian, agreed with Tolbert but pointed out that the malady had an insidious nature because people were often "homesick for a place that could never be their home."[1]

It has always been difficult to exist in this arid land. The early Indian villages were all situated along the banks of the Rio Grande or smaller tributaries to make use of the water and the fertility of the alluvial plains that appeared after the high waters carried soil

Aerial view of Canyon Colorado, better known as the River Road over the Big Hill. This view is to the west, looking up the Rio Grande that can be seen for miles to the left of the also winding road. Until that masterpiece of road construction was completed a couple of years ago, this part of the Big Bend was impassable. Today it is the route of the Camino del Rio. Picture made September 22, 1965.

and deposited it as the floods receded. Life was so precarious that a drought, a crop failure, or another type of natural disaster often destroyed entire villages or forced them to relocate in other areas. Even an environmental shift could upset the delicate balance that allowed the Indians to cling to a subsistence form of agriculture in the river valleys.[2] Archeologists have located early villages along the Rio Conchos, near its confluence with the Rio Grande, and on the right bank of the Rio Grande.[3] The settlement called Tapalolmes, located near the present site of Redford, Texas, was well established in 1747 when Rabago y Teran observed it during his travels. The natives later crossed the river and built a settlement on the left or west bank.[4] Other villages had been observed and described over a hundred years earlier. The intrepid Spanish explorer Cabeza de Vaca crossed the Rio Grande in 1535, but the exact location of his route has been a subject for lively debate among historians, geographers, and geologists. There is little doubt that he visited the La Junta de los Rios (the confluence of the Rio Conchos and the Rio Grande) area, named the local Indians "the people of the cows," erected a cross, and designated the area "La Junta Pueblo de las Cruces."[5] Robert T. Hill, the famous American geologist of the Trans-Pecos region, maintained that de Vaca wandered from a location near the present site of Ft. Davis on a southwestern course that carried him down Terlingua Creek to Lajitas and then across the Rio Grande at or near the famous San Carlos ford. He then continued on a southwestern heading but reversed his course and took a northern route to La Junta.[6] Hill based his findings on de Vaca's accurate descriptions of the geographic and geologic features he passed in west Texas. Hill was unable to understand why a large number of historians had been unable to correctly plot de Vaca's route.[7]

Many of the early settlers of the Big Bend area and the people that lived along both sides of the Rio Grande who were present when de Vaca came through west Texas were cave dwellers. They spent part of their time in dry caves above the river and the rest of it along the rivers and arroyos planting and harvesting crops.[8] A larger and more organized tribe, the Jumanos, were active in the La Junta area from 1650 until the 1770s. They were first critically observed when the Antonio de Espejo expedition passed through the La Junta area in 1582-1583. They were good farmers but never practiced irrigation, a fact that brought starvation as a constant visitor to the tribe. The Jumanos possibly were related to the pueblo-building tribes who spread southward along the Rio Grande. They allied themselves with the Apaches, their former enemies, during the 1693-1715 period, yet there was still a gradual reduction in the size of their tribe during the 18th century.[9] There is very little accurate information available on this tribe, and, as Newcomb states, "of all the Texas Indians, the Jumanos are the least known, and the few facts about their culture we do possess seem to raise more questions than they answer."[10] He concludes that they were "an important outpost of civilization, a pioneer people who had been temporarily successful in establishing settlements on the fringe of Puebloland."[11]

The Jumanos and the other tribes of the southwest were often viewed as subjects for conversion to Catholicism. A number of *entradas* and *visitas* crossed into the Trans-Pecos area, commencing in 1581 when the Fray Augustin Rodriquez expedition reached La Junta on July 6.[12] Composed of three priests, a sergeant, 19 Indian scouts, and 600 head of cattle, sheep, goats, and hogs, its major purpose was to explore the territory and christianize the natives.[13] The Espejo *entrada* left San Bartolome in early November, 1582, with a complement of 15 soldiers, some servants, a priest, and over 100 horses and mules, to rescue the members of the Rodriquez expedition. Espejo, a wealthy Mexican citizen who was attempting to atone for a crime he had committed, financed and led the expedition as it marched up the Conchos River to the Rio Grande. On December 9, 1582, it arrived at La Junta, where the horses were rested for eight days before it headed northward to El Paso del Norte.[14] Espejo eventually led his men farther north to Santa Fe, then east to the Pecos River, down it to the Sheffield Crossing, west to Kokernut Springs (Alpine), and then down Alamito Creek to the Rio Grande, just south of Presidio, Texas.[15] The Dominquez de Mendoza expedition explored the area north and east of La Junta and travelled up Alamito Creek to Alpine.[16] Both the Espejo and Mendoza expeditions opened a new trade route from Mexico to the United States that remained virtually unused for a century and a half.

An American expatriate was the first man to realize the value of the route that the early explorers had found. Dr. Henry Connelly was a Kentucky physician who moved to Chihuahua, Mexico in 1828. He worked as a clerk in a retail store for a Mr. Powell, saved his money, and later bought the business from Powell. Dr. Connelly left Mexico in April, 1839 via the Rio Conchos to La Junta, crossed the Rio Grande, and headed up Alamito Creek. Eventually he reached his destination, Independence, Missouri. There he loaded either pack mules or a wagon train with goods to sell in Mexico. His first round trip lasted 16 months and was very successful. With Edward J. Glasgow, another American expatriate in Chihuahua, he formed a partnership that continued in

The Crawford Ranch and small farm in Fresno Canyon, lower part of Brewster County, about 1918. It was in an isolated location, but several Army mule pack trains passed by every week, going to and from Lajitas when a cavalry troop was on the Rio Grande. Through the Fresno Canyon was the main route between Lajitas, Terlingua and Marfa then, but not after 1920. Mr. Crawford had the largest goat herd in this part of the Big Bend, and he also grew the first citrus fruit in this part of Texas (oranges and lemons).

a profitable manner until the end of the Mexican War in 1848. Connelly married a Mexican woman and fathered three sons before he moved to the United States States just after the Treaty of Guadalupe-Hidalgo was signed. In 1849 he settled in the New Mexico Territory where he purchased the largest mercantile store in the region. In 1861 and again in 1864, President Abraham Lincoln appointed him territorial Governor, a post he held until the time of his death in 1866.[17]

Connelly's Trail, better known as the Chihuahua Trail, opened a prosperous era for the Missouri merchants and for the Rio Grande Valley area near La Junta and Presidio. After the Rio Grande was finally and firmly established by the Treaty of Guadalupe-Hidalgo as the boundary between the United States and Mexico, new residents began slowly to settle along the river in order to profit from the growing commerce between the United States and Mexico. One of the earliest settlers was Ben Leaton who relocated near the San Jose Mission in 1848 on some land that his wife, the former Doña Pedraza, had purchased in 1833. Leaton, who was born in Kentucky and later lived in Chihuahua, opened a very lucrative trading post, El Fortin. Later called Fort Leaton, it attracted business from the Indians, American travellers and merchants, and Mexicans who crossed the river to trade. Leaton, a mysterious man, disappeared in the early 1850s, setting off a long and complicated series of court battles over his land.[18] Fort Leaton is in the process of being reconstructed on its original location several miles south of Presidio near the mouth of Alamito Creek.[19]

Fort Leaton, the outpost of civilization in the Big Bend region, was a favorite stopping point for Americans who crossed the Chihuahua Trail or who were exploring the area. One of the first groups of visitors included Colonel Jack Hays. He had been commissioned, along with Samuel Highsmith, to find a new trade route between San Antonio and El Paso del Norte. Businessmen in San Antonio had raised over $800 to finance the expedition of 35 Texas Rangers and Indian guides. They left the Alamo City in August of 1848, undoubtedly never believing that they would almost starve to death before reaching the security of Fort Leaton in late October.[20] Samuel Maverick, a veteran of the Mier Expedition and the

Mexican War, kept a detailed diary that indicates the problems they encountered. It took a month to reach the Devil's River. After crossing it, they entered the Big Bend region and became lost. Maverick's diary illustrates their suffering. September 29: men were "crawling like flies on side of mountain." October 2: "To banks of the Rio Grande, where we killed and ate a panther." October 4: "Mustang meat in request." October 7: "No food. Here we begin to eat bear grass." October 10: "Killed a mule. Meat poor and tough." On October 19, the weary band reached the small Mexican town of San Carlos, mainly through some directions a group of Indians had given them, and obtained bread and milk to restore themselves.[21] They travelled north from San Carlos, crossed the Rio Grande, and spent 16 days at Fort Leaton recovering from their ordeal and resupplying for their return trip to San Antonio. Hays ruled out any thought of a continuation of the trip to either El Paso de Norte or Chihuahua City.[22] Although the Hays-Highsmith group was the first expedition to reach Fort Leaton from San Antonio, the results of the trip were not impressive or satisfactory. One member of the party, Dr. Wahm, went insane and deserted as the expedition wandered aimlessly in the Big Bend region. The Indians found and cared for him and later permitted him to return to San Antonio a year and a half after he first left with Hays and Highsmith.[23]

The year after the Hays trip, the United States Army, eager to find a shorter route to the west, dispatched Lieutenant W. H. C. Whiting of the Corps of Engineers to seek a safe route from San Antonio to El Paso del Norte. He had difficulty traversing the Trans-Pecos area but reached Fort Leaton in six weeks. He resupplied there and enjoyed the type of hospitality that made Ben Leaton famous throughout the west. Whiting recorded in his diary that he dined on stewed chicken with chili, tortillas, roast turkey, frijoles, coffee, and whiskey, with Leaton's famous peach brandy as an after-dinner drink.[24] Whiting and his assistant, Lieutenant W. F. Smith, continued up the Rio Grande to El Paso del Norte and returned to San Antonio via a new route that ran southwest between the Pecos and San Pedro Rivers to Las Moras Creek and then into San Antonio. It was an improved route that covered an estimated 645 miles.[25]

Following Whiting's successful mission, the Army attempted to find a shorter and safer route to El Paso del Norte via the Rio Grande. Captain John Love proceeded from Ringgold Barracks, near Rio Grande City in the lower valley, up the river to a spot he estimated as 1,014 miles from his starting point. He led a company of a dozen men, using a flat-bottomed boat that measured 50 by 16 feet and drew only 18 inches of water. They used this boat for what he estimated to be the first 967 miles, but at Brooks Falls they changed to a smaller boat that took them to an impassable point they believed was 25 miles south of Presidio. While they failed to navigate all the way to El Paso del Norte, they considered they had proved that over a thousand miles of the Rio Grande was navigable, even if only in small boats.[26] Love's report was quickly contradicted in another Army document that stated that the Rio Grande was only ten inches deep above Eagle Pass and thus impassable much of the year. The second report, the work of a small party of Army men under the command of Lieutenant Martin Luther Smith, was based on a trip via flat boats to a point eight miles above the confluence of the Rio Grande and the Pecos Rivers.[27] Despite Capt. Love's optimistic report, the Rio Grande was not the best route from San Antonio to the Big Bend Region, El Paso del Norte, or Chihuahua City.

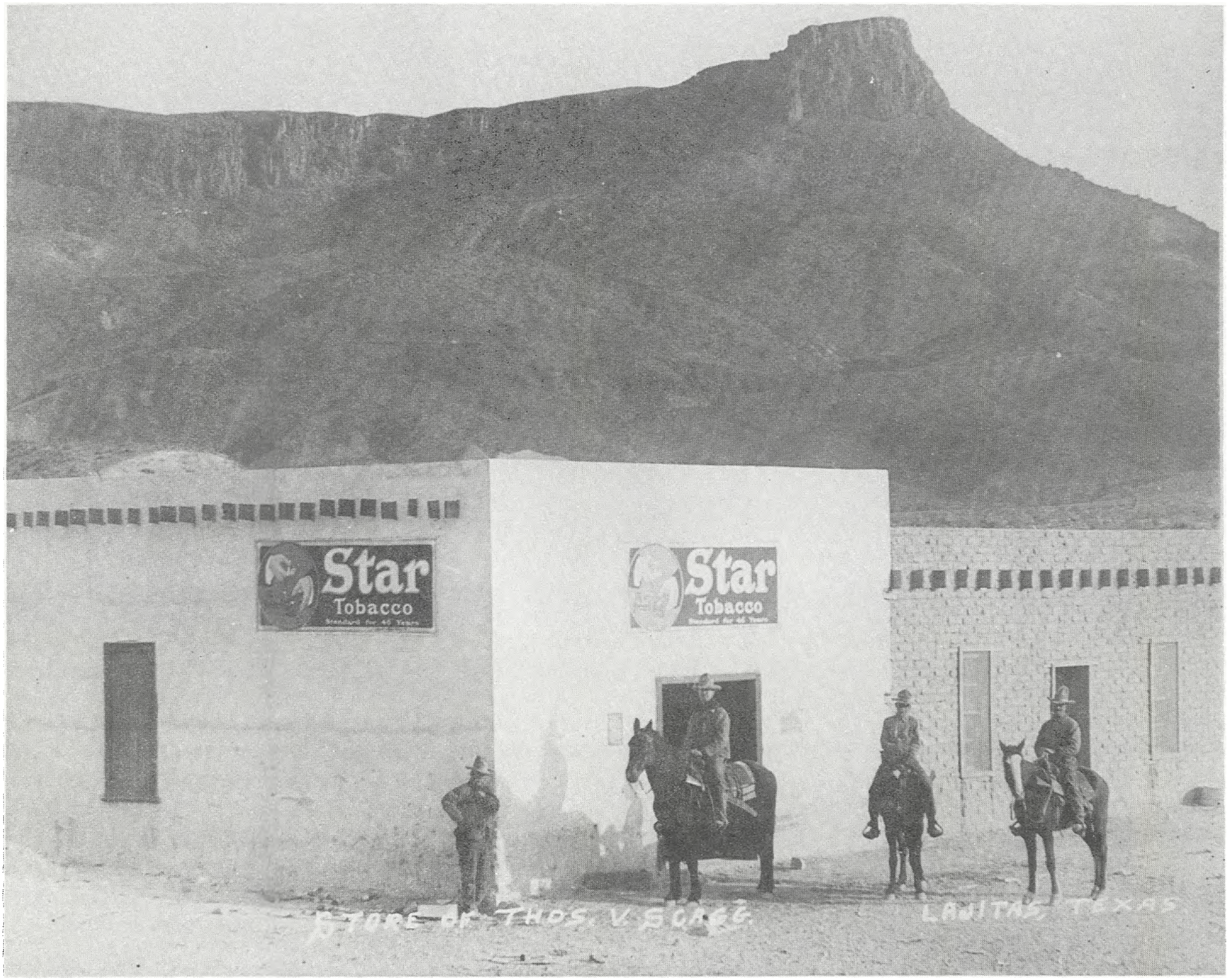
American interest in the exploration of the southwest continued for other reasons. Pursuant to the terms of the Treaty of Guadalupe-Hidalgo, the United States Army organized a number of reconnaissance missions that were ordered to survey carefully the border region along the Rio Grande. John Russell Bartlett was the first Boundary Commissioner, but his poor knowledge of the west, problems with the Indians, disagreements with Mexico, and a shortage of funds sharply curtailed his effectiveness.[28] Major William H. Emory, an astronomer attached to the Topographical Corps of the United States Army, assumed command of the surveying party as it started to work its way south along the Rio Grande to its mouth. Emory faced numerous problems that included the severity of the climate, lack of funds to pay his men or purchase supplies, and the rugged nature of the terrain he had to map. Emory and his skilled assistants carefully classified and catalogued the flora and fauna they found along the length of their route. They were most impressed when they travelled from Fort Leaton south toward the canyons of the Rio Grande. Emory remarked that it was "a section of country which for ruggedness and wilderness of scenery is perhaps unparalleled."[29] They observed that a one-to-three-mile-wide valley extended from Fort Leaton south to the Bofecillos Mountains where it narrowed to form a canyon. Farther to the south, near the present Lajitas Trading Post, Emory reported that the Comanche Pass ford was the "most celebrated and frequently used crossing place of the Indians."[30] He happened to meet Chief Mano of the Apache Tribe who was leading a band of men through the ford to Durango, Mexico.[31] Emory's work in the Big Bend region was the first detailed scientific exploration completed in the Big Bend region, but other men who followed added more information to his collection of samples and observations.

All of these explorations of the area and the continued expansion of American interests convinced several Americans living in Mexico that the border region along the Rio Grande near Presidio and immediately to the south held the promise of commercial success. Milton Faver, like Ben Leaton, came to Presidio after living in Mexico and marrying a Mexican woman. He ran a freight line between Ojinaga (near La Junta) and Meoque and later operated a general store in Ojinaga, but he finally moved to the west bank of the Rio Grande and eventually owned four large ranches to the north and east of Presidio. He was one of the most successful ranchers in the region and amassed a herd of over 20,000 longhorns before his death in 1889.[32] John W. Davis settled near Alamito Creek where he raised horses and cattle in the 1850s. He employed between 15 and 20 Mexican families to operate his ranch. He decided to leave the southwest in 1892 to return to his native North Carolina after the death of his Mexican wife.[33] John W. Spencer, one of Leaton's original business partners, moved with his Mexican wife and large family to the American side of the river in the 1850s to enter the horse-raising business near Fort Davis. The Indians stole most of his stock, so he moved back near the Rio Grande for security reasons, settling north of Presidio and entering the cattle business.[34] John D. Burgess, another early businessman in the Presidio area, followed the same general pattern as Leaton and Spencer. He entered the freighting business in 1851 and then bought some land on the American side of the river and went into competition with Leaton. He took over Leaton's Trading Post and continued to work in the freighting business for the next 20 years. He became entangled in a bitter feud with several of Leaton's heirs, including the new husband of Leaton's widow.[35]

Both Burgess and Leaton recognized the need for adequate transportation in the Big Bend area. The freighting business was a lucrative occupation for many individuals who ran lines both in Mexico and the United States and profited from the growing trade between the two nations. Connelly's Chihuahua Trail was the first successful route connecting northern Mexico with the American midwest, but other routes were needed. In 1869 August Santleben inaugurated a stagecoach route between San Antonio and Chihuahua City via Fort Stockton and Presidio. He made a number of round trips in the 1870s, carrying goods of all types, especially silver from the Mexican mines. In 1876 he attempted to organize a large-scale freighting business in Chihuahua City, but the completion of the El Paso del Norte-Chihuahua City railroad forced him to abandon his plans.[36] Henry Skillman's San Antonio-El Paso mail route, established in 1850, was extended to Presidio on the Rio Grande on a weekly basis in 1870 and brought the area into closer contact with the rest of Texas and the United States.[37] Drivers on the Chihuahua Trail used the prairie schooner as their principal vehicle. It had a bed 24 feet long but was only 4½ feet wide with wooden sides that extended to a height of 5½ feet. The rear wheels were almost six feet high, while the front wheels were a foot shorter. A team of 16 mules pulled an average load of 14,000 pounds. Drivers had to have the skills of a mechanic, a veterinarian, a gunfighter, an overland navigator, a cook, and a businessman to survive on the trail.[38] The advance of the railroad hastened the end of mule-drawn freight wagons and the lines that served many remote areas in the southwest. The Rio Grande area was bypassed in 1883 when the Southern Pacific Railroad crossed the Trans-Pecos region to the northwest of the river, helping to found and promote the towns of Sanderson, Marathon, Marfa, and Valentine along its route. A line did not reach to the Rio Grande until 1930 when the Atchinson, Topeka and Santa Fe linked Alpine and Presidio and provided a connection, via the Mexican National Railroad, to the west coast of Mexico.[39]

Adequate transportation and the location of United States Army posts in the southwest were closely connected to the success of the cattle business in the Big Bend area. Railroads were used to bring in many of the initial herds and to transport the steers to the markets in the midwest. The location of a major Army garrison at Fort Davis in 1854 had an important impact on the establishment of the cattle business in the Big Bend since the demand that Fort Davis generated for fresh beef helped to accelerate the growth of many ranches.[40] Frequent Indian raids, a hot and arid climate, and the long distances to markets continued to frustrate many ranchers. The rich grasses of the region, especially the numerous varieties of grama grasses, that existed in "the most profuse abundance over the entire surface of these table lands, is nutritious during the whole year, and the plains between the Rio Grande and the Pecos seem intended by nature for the maintenance of countless herds of cattle."[41] The early cattle were Mexican and Spanish breeds, but these were gradually replaced as the Texas longhorns were brought into the area. The longhorns, which were seen in many colors, interbred with the native stock to produce a large wild animal that could survive on the native grasses without requiring large amounts of water.[42] Early cattle drives were organized in the 1860s, headed not toward the markets in the midwest but along the Chihuahua Trail into Mexico. These drives, which reached their peak in 1868-1869, were safe from Indian attacks but often fell prey to the raids of the Mexican rustlers that attacked along the route.[43] The most prosperous period for the cattle industry in the Big Bend region came in the 1880s. A land rush during the first part of the decade resulted in the formation of many large ranches. J. T. Gano founded the Estado Land and Cattle Company in 1885 on 55,000 acres with 6,000 head of cattle he brought in from Dallas and Uvalde.[44] Meyer Halff started his ranch with 50,000 acres and added more later while Milton Faver in the 1880s controlled four large ranches with between 10,000 and 20,000 head of cattle.[45] The severe winter of 1885-1886 helped to push over 60,000 head of cattle into the Big Bend, but it proved disastrous as they quickly overgrazed much of the open range. The first large-scale cattle roundup was held the following summer, August, 1888, to sort out the strays and to help preserve the rapidly diminishing grasslands.[46] The introduction of barbed wire in 1888 and the appearance of the Hereford about the same time ended the first significant era in the cattle business.[47]

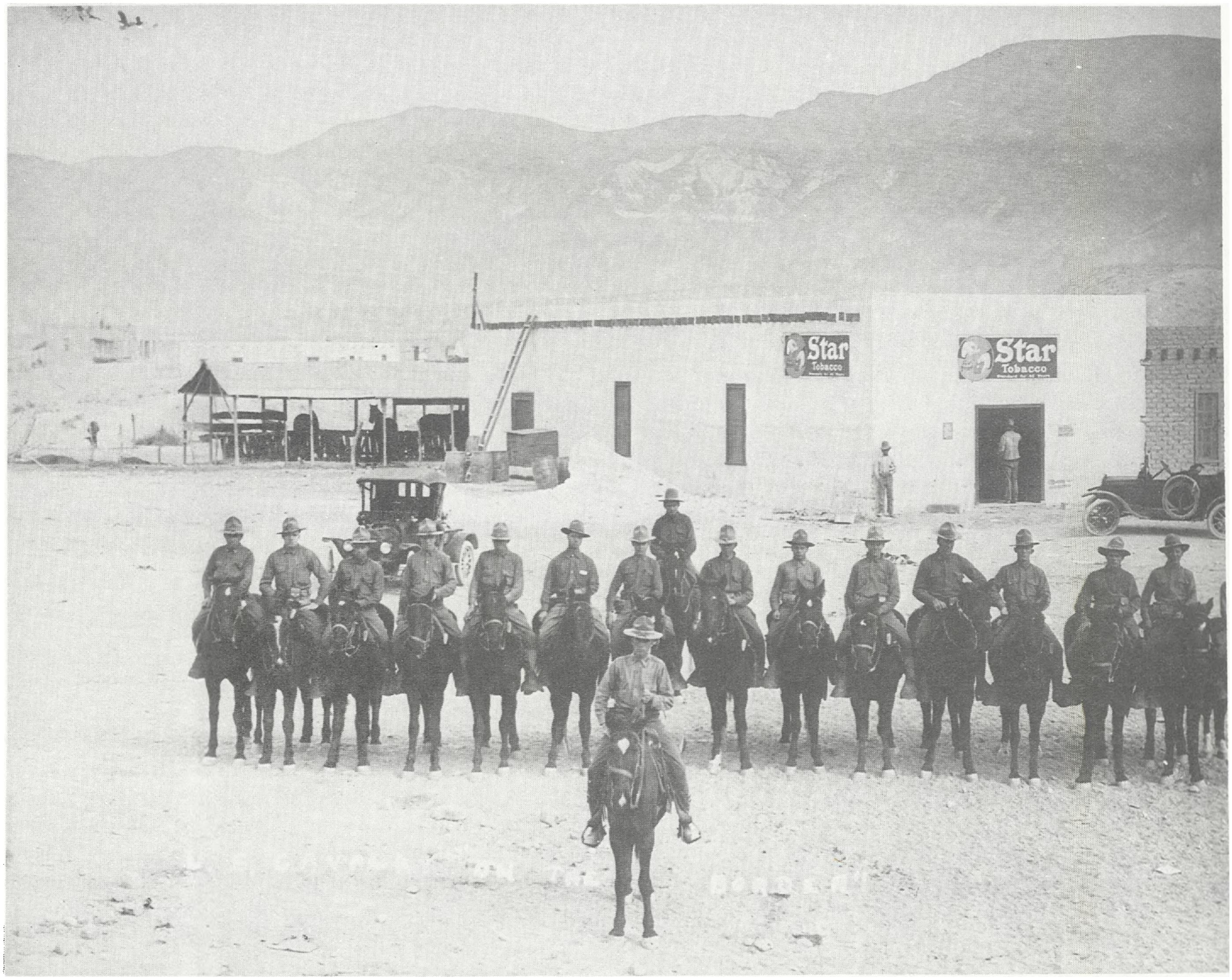
Less romantic, but still economically significant to



The trading post farthest from a railroad on the Mexican border was at Lajitas, Texas. It was 108 miles from Alpine or Marfa, Texas. From 1911 through 1920, it probably was also the busiest for in that period its regular large Mexican border trade area on both sides of the Rio Grande was made larger by the numerous quicksilver mines nearby. The largest mine at Terlinqua had its own store but the small mines did not. This picture of Thomas V. Scaggs' Trading Post at Lajitas, Texas, was made in 1916. It shows Scaggs at the corner of his store building talking to Texas Ranger Jeff Vaughn, Cavalry Officer Lt. Stilmax, and Texas Ranger Bill Palmer. A troop of the 6th Cavalry and these two Texas Rangers were stationed at Lajitas.

the area, was the sheep industry that Milton Faver founded. He was the first important sheepman to battle the cattlemen for a place on the open range for his flocks in the 1880s.[48] Although the first sheep were introduced in the La Junta region in the 1560s, they did not play a major role in the economy until three centuries later when their total economic value exceeded the value of all the cattle in Texas.[49] Ranchers like Faver fought for the sheepmen, introduced improved breeds, and persuaded others like George Crosson to enter the business. Crosson bought 1,800 ewes from Faver's large flock in the 1880s and was able to enlarge his own holdings to over 20,000 head by 1889.[50] The 1892-1893 drought crippled the sheep business in the Big Bend, and the Cleveland administration's interference with the Wilson-Gorman Tariff of 1894 caused a large reduction of the duty on raw wool that dealt another serious blow to the sheep raisers of the United States, especially in Texas. The sheepmen of the Big Bend did not recover from these disasters until the 1930s.[51]

Although the region along the Rio Grande was somewhat better suited for livestock, a number of successful farms were started in the 1870s. Using water from the river to supplement the limited rainfall on the rich alluvial soils, farmers were able to "raise any crop that grows in Texas," according to an early report from a civil engineer. "Its (the area between Presidio and Redford) yield is enormous, as much as 80 bushels of corn and 50 bushels of wheat being grown to the acre."[52] Irrigation of these fertile lands began in the 1870s just south of Presidio and



This picture was made in 1916 at Lajitas Texas, of Thomas Scaggs Trading Post and part of a troop of the 6th Cavalry. It is not known which troop these troopers belonged to as the troops were rotated. The officer was Lt. Stilmax. The cavalry had its stables at the rear of the trading post when this picture was made but later moved them beyond the second large white building.

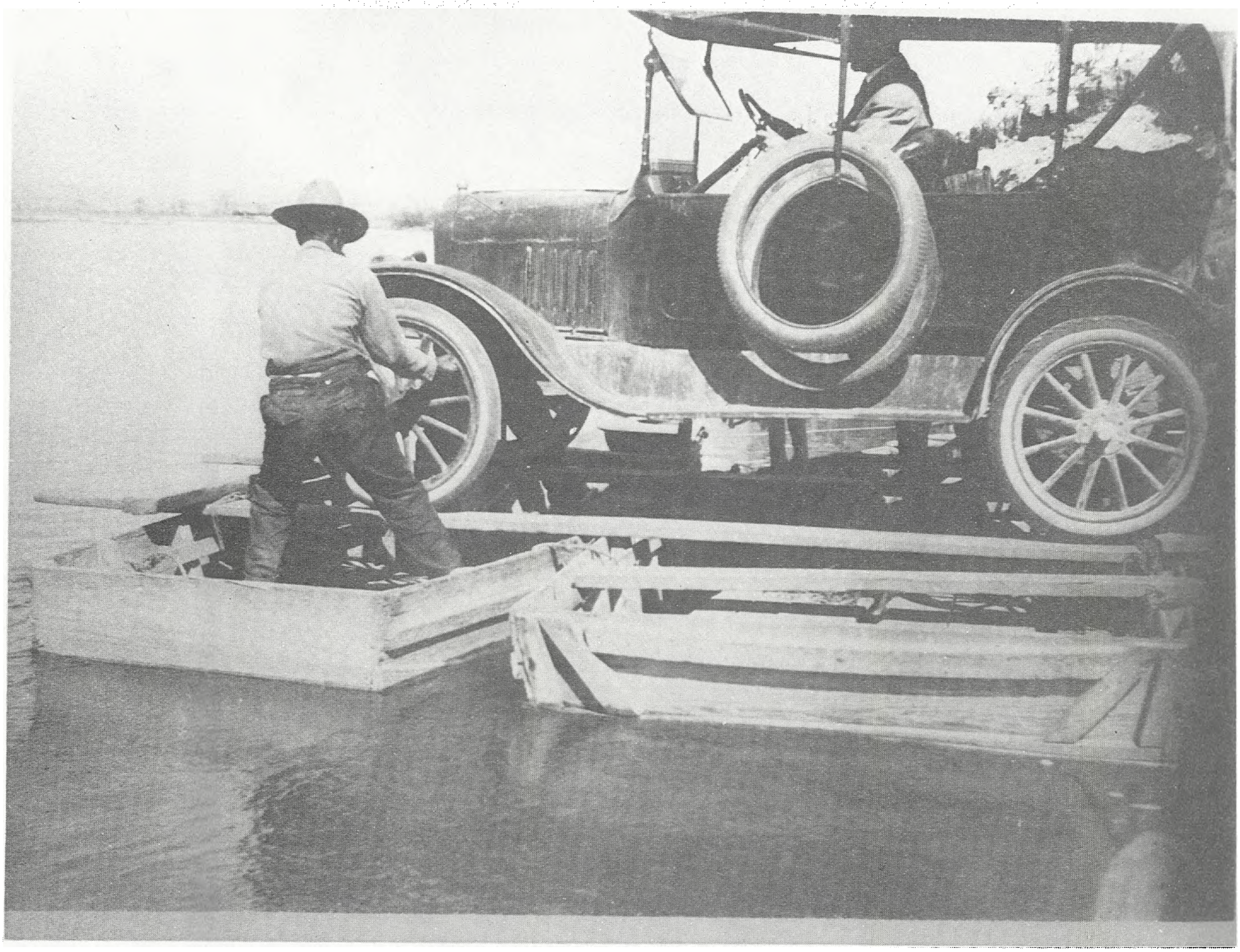
Two wagons pulled by burros and loaded with handmade ropes were being hauled from Lajitas 108 miles to Alpine, Texas, in 1921. They were made by Mexicans in Mexico, sold to Scaggs' Trading Post in Lajitas, Texas, as there was no market for them in this part of Mexico, where everybody made their own ropes.

extended to Redford. One of the earliest farmers in the area was Secundio Lujan who obtained a quarter section of land (160 acres) from the state of Texas in 1875. To obtain water from the river to irrigate his land along its course, he formed the Polvo Irrigation Company. It constructed a 550-foot dam of loose rock, from two to four feet high, that channeled water into an irrigation canal five miles long, six feet deep, and six feet wide at the top. To blast through the hard, igneous rock that he found along the route of the canal, Lujan had to travel over 200 miles to Chihuahua City to purchase gunpowder. He was a very successful farmer, growing beans, onions, corn, and wheat, and later concentrating on cotton.[53] Cotton production totalled 97 bales in 1921 but increased dramatically to 4,789 bales in 1930.[54] Recently farmers have concentrated on onions and the famous Presidio cantaloupes.[55] Other crops just north of the Polvo/Redford area included beans raised after crops of oats, barley, and wheat had been harvested. A few crops, such as corn and beans, were occasionally grown without the benefit of irrigation, usually just north of Presidio where the water level of the Rio Grande was unpredictable and often too low to permit construction of irrigation projects.[56]

As the twentieth century neared, the arid region along the Rio Grande was relatively prosperous but still thinly settled. Presidio County had only 580 residents in 1860 and 40 years later could boast of an increase to 4,125, a substantial gain but very few residents considering the size of the county.[57] Transportation was still slow and difficult, but improving. Ranching and farming occupied most residents. Silver mining developed into a major industry at Shafter, about 30 miles from the river, where the metal was first discovered in 1882 and mined continuously for 40 years. An estimated two million tons of ore produced about $20 million in silver during the operating days of the mines.[58] Farther south, cinnebar, the ore for mercury (commonly called quicksilver) was mined from 1892 until 1971.[59] About one-fourth of all the mercury produced in the United States came from these mines.

One other important natural resource of the area is the native candelilla wax plant (*Euphorbia antisyphilitica*). It grows in abundance on the colluvial limestone slopes and gravel terraces on both sides of the Rio Grande. The plant is harvested and boiled in an acid bath to produce a high-quality wax which is used in chewing gums, floor and auto polishes, crayons, cosmetics, lubricants and a variety of other products. Wax produced in Mexico is supposed to be marketed through the Bank of Mexico, although much of it finds its way across the border and is marketed with the relatively small quantity of wax produced in Texas.[60]

The growing prosperity of the area along the Rio Grande was threatened in the first two decades of the twentieth century when the political and social unrest that spread across Mexico spilled into the United States. In the early part of the century, the Big Bend area had been relatively peaceful since the last raids of the Indians had been effectively ended in the 1880s when a large force of American soldiers had been stationed in a series of forts along and near the border. Francisco (Pancho) Villa, the Mexican bandit and outlaw, often crossed the border into Texas when the Mexican authorities were chasing him. He occasionally hid with his men in the Alamito Creek area, safe from capture but a threat to the stability and peaceful nature of the area.[61] The United States Army was ordered into the area in 1916. A small detachment of cavalry was stationed at the Lajitas Trading Post, and others were garrisoned at Marfa. Aircraft permitted the early pilots of the U.S. Army Signal Corps to patrol the river and locate potential problems before they grew too large to handle.[62] Border raids were common throughout this period.



In 1921 when this picture was made, and earlier, the Rio Grande always had more water than it has today. Then there were not as many large irrigated farms along it. At Lajitas, where this picture was made, occasionally an auto had to cross the Rio Grande, as this Model T Ford of a Texas mining man who had been to San Carlos or some other mining town in the state of Chihuahua. There was a Mexican at Lajitas who had a couple of wooden flat bottom boats that could be converted into ferry boats big enough to cross an auto, as this picture shows.

An estimated 80 Mexican bandits crossed the border during the night of May 5, 1916, to raid both Glenn Springs and Boquillas, Texas. A number of residents were killed, including several American soldiers. President Wilson retaliated by sending a large force to patrol the border region. Another serious raid occurred more than a year later at the Brite Ranch, located near Valentine.[63]

While ranching and farming continued and the border bandits crossed the river to rustle cattle and rob storekeepers, another new industry for the Trans-Pecos area was being established. Robert T. Hill, a geologist, was perhaps the first person who recognized the natural beauty of the Trans-Pecos region, especially the area along the Rio Grande. He planned and led the first successful expedition that explored the Rio Grande from Presidio to Langtry.[64] He ordered the lumber for his three boats shipped from San Antonio to Del Rio where he assembled them and then forwarded them to Marfa via the railroad. Hay wagons carried the thirty-by-three-foot boats the last 75 miles to Presidio. Warnings of impassable boulders in the river, of an outbreak of small pox in Presidio del Norte, and of Mexican bandits who roamed the area frightened off two members of the eight-man expedition before it even got to the river.[65] Although the International Boundary Commission said the river was impassable, Hill set out with five men on October 5, 1899. On the second day of the trip they reached Polvo (in Spanish "dust"), "an appropriately named village" of a half-dozen adobe houses and a store.[66] Stopping to investigate, Hill met the storekeeper, Samuel J. Hensley, who pointed out spots of dried blood on the floor and walls that had resulted when a Mexican bandit had murdered his predecessor several months earlier.[67] Hill and his companions had been warned about a notorious bandit named Alvarado, or "Old White Lip" because half of his moustache was black and the other half white.[68] Although the party did not see "Old White Lip," he was in the vicinity, and several months after Hill had completed his trip, Hensley wrote that Alvarado had robbed a man of $1,200 and assaulted his wife near the area where Hill and his men had camped. Shortly afterwards, the Mexican police shot and killed Alvarado and one of his lieutenants.[69] To prevent any attacks, Hill ordered one man to stand guard over the members of the expedition while they were portaging their boats or when they were sleeping. The 600-foot walls of Colorado Canyon, the geological formations, the wind-eroded rocks, and the size of Santa Elena Canyon all impressed Hill.[70] His descriptive coverage of the river trip that appeared in *Century Magazine*, along with his other field work in the Trans-Pecos area, helped to stimulate interest in the region along the Rio Grande.

Although tourism was increasing and the scientific community had begun to take an active interest in the natural features of the area, ranching continued as the most important economic activity. Older ranches, like the C. H. Madrid spread founded in the 1870s, survived the severe drought of 1892-1893 and were prospering in the 1920s. The Madrids built a water system from a spring to the ranch house and maintained a small orchard of peach, orange, and fig trees, using the irrigation system they had constructed.[71] The D. H. S. Smith ranch, a short distance north of the Madrid Ranch and in Fresno Canyon, grew out of a land grant to the Dallas and Wichita Railroad in 1881. J. L. Crawford later assumed control over it, but sold it to Harry Smith in the 1930s. Smith grazed from 3,000 to 4,000 Angora goats on the ranch, despite the attacks of coyotes, panthers, bobcats, and wolves.[72] Joe Brady bought the large ranch in 1941, installed more water lines, and raised cattle. He used wetback labor that came to him for jobs from across the Rio Grande. The "river telegraph" and possibly "avisadores" kept the work force advised of the location of the Border Patrol and the wages and working conditions on the various ranches on the Texas side of the river.[73] Brady sold the acreage to an Ohio man named Mooney just after World War II. He later sold part of the land to the Fowlkes brothers, owners of the neighboring ranch. Mooney left Texas, although he still owned a part of the land, including the ranch house and the surrounding orchard, both of which have suffered in recent years from a lack of maintenance.[74]

The Fowlkes brothers, Edwin and Manny, came to the Big Bend area shortly before World War II from Jeff Davis County to the north and gradually put together a large (almost 200,000-acre) ranch north of Redford. The severe seven-year drought of the 1950s, among other factors, resulted in the Fowlkes brothers' sale of the ranch to the Big Bend Ranch Corporation, which in the 1960s sold to Robert Anderson's Diamond A Cattle Company. Anderson continues to operate the large ranch, which, by lease or purchase now contains about 320,000 acres, straddling two counties, Presidio to the west and Brewster to the east. He grazes cattle in the Fall and Spring and opens it to hunters during the deer season. An ardent conservationist and naturalist, Anderson has permitted many scientific groups to visit and explore the Solitario, a large partially eroded laccolith that stands virtually undisturbed on the eastern edge of his ranch property. Its outstanding geological formations, archeological sites, flora, and fauna form a large open research site for many scientists.

Life along the river continues at the same leisurely pace that de Vaca must have observed over 400 years ago. But new interest in the scientific treasures of the area, in the beauty of the mountains and the arroyos, and in the desire to enjoy the vast openness of an undisturbed region has brought more people than ever to this remote sector of Texas. Following the modern highway south from Presidio, a visitor can see the green farmland on the alluvial plains of the Rio Grande, pass through the small town of Redford, and approach the first of the numerous breathtaking canyons of the Rio Grande. Driving along the river in air conditioned comfort, it is hard to imagine that de Vaca walked through this area, or that Echols drove camels on this route from Presidio in 1860, or that Colonel Jack C. Hays and his men wandered for 12 days without food just to the south of this spot. Just below Black Rock Canyon, the small village of Lajitas, population nine, slumbers in the warm sun. Again, it is hard to picture elements of the United States Cavalry garrisoned at the Trading Post or the international transactions for cattle being conducted on a sandbar in the middle of the river. It is even more difficult to visualize the Comanche bands as they once swooped down their trail to cross the San Carlos Ford to invade Mexico to loot and kidnap the natives. The full September moon was known as the "Mexican Moon" in Comanche camps as it signaled the time for another raid, but in northern Mexico the same moon was called the "Comanche Moon," and people fled to the mountains to protect themselves and their property.

Farther to the south of Lajitas lies the awesome Santa Elena Canyon that lured Robert T. Hill in 1899 and today attracts thousands of outdoorsmen and adventurers who paddle their canoes and rubber rafts down the river between the canyon's steep walls. It is now part of a 700,000-acre national park that was formed after the land was given to the National Parks Service. Big Bend National Park protects the natural beauty of the area and guards the flora and fauna of this unusual region from destruction. The area just above the park, rich in natural beauty and with a wealth of scientific treasures, would be enhanced by the same type of protection to preserve its rich historical background.

Pictures and captions of photographs in this section are from The Smithers Collection, Photography Collection, Humanities Research Center, The University of Texas at Austin.

NOTES

1. William O. Douglas, *Farewell to Texas: A Vanishing Wilderness* (New York, 1967), 48. This current brief survey was written without the benefit of Ronnie C. Tyler's *The Big Bend: A History of the Last Texas Frontier* (Washington, 1975), a very thoughtful and detailed treatment of the area, which appeared in print after the survey had been completed.

2. J. Charles Kelly, "Factors Involved in the Abandonment of Certain Peripheral Southwestern Settlements," *American Anthropologist,* 54 (July-September, 1952), 382-385.

3. See J. Charles Kelly, "The Historical Indian Pueblos of La Junta de los Rios," *New Mexico Historical Review,* 24 (October, 1952), 251-295 and 28 (January, 1953), 21-51 and also Howard G. Applegate and C. Wayne Hanselka, *La Junta de los Rios Del Norte y Conchos* (El Paso, 1974) 2-23.

4. Kelly, "Historical Indian Pueblos," 28 (January, 1953), 40-41.

5. Cabeza de Vaca, "The Narrative of Cabeza de Vaca," trans. by Frederick W. Hodge, in Hodge, ed., *Spanish Explorers of the Southern United States,* 1528-1543 (New York, 1907), 99-105.

6. Robert T. Hill, "Cabeza de Vaca Crosses the Rio Grande at Last," *Dallas Morning News,* March 11, 1934, 8.

7. *Ibid.*

8. Victor J. Smith, "Survey of Indian Life in Texas," West Texas Historical and Scientific Society *Circular,* No. 5 (1941), 8-10.

9. W. Newcomb, *The Indians of Texas: From Prehistoric to Modern Times* (Austin, 1961), 228-234 and Herbert H. Bolton, "The Jumano Indians in Texas, 1650-1771," *Southwestern Historical Quarterly,* 15 (July, 1911), 66-84.

10. Newcomb, *The Indians of Texas,* 224.

11. *Ibid.*

12. Applegate and Hanselka, *La Junta de los Rios,* 13-14 and Victor J. Smith, "Early Spanish Explorations in the Big Bend of Texas," West Texas Historical and Scientific Society *Publication,* No. 2 (1920), 56.

13. Herbert E. Bolton, ed., *Spanish Exploration in the Southwest, 1542-1706,* (New York, 1908), 138-139.

14. Bolton, ed., *Spanish Exploration in the Southwest,* 161-164 and Smith "Early Spanish Explorations in the Big Bend," 57-58.

15. Applegate and Hanselka, *La Junta de los Rios,* 14.

16. J. Charles Kelly, "The Route of Antonio de Espejo Down the Pecos River and Across the Texas Trans-Pecos Region in 1583; Its relation to Texas Archeology," West Texas Historical and Scientific Society *Publication,* No. 7 (1939), 7 and Smith, "Early Spanish Exploration in the Big Bend," 59-68.

17. William E. Connally, ed., *Doniphan's Expedition and the Conquest of New Mexico and California* (Topeka, 1907), fn. 65, 276-282.

18. J. J. Bowden, *Spanish and Mexican Land Grants in the Chihuahuan Acquisition* (El Paso, 1971), 194-208.

19. For a general review of Leaton, see Levitt Corning, *Baronial Forts of the Big Bend: Ben Leaton, Milton Faver and the Private Forts in Presidio County* (San Antonio, 1967), 19-41 and Elton Miles, "Old Fort Leaton: A Saga of the Big Bend," in Wilson Hudson, ed., *Hunters and Healers: Folklore Types and Topics* (Austin, 1971), 83-102.

20. James K. Greer, *Colonel Jack Hays* (rev. ed., Waco, 1974), 217-225; Averam C. Bender, "Opening Routes Across Texas," *Southwestern Historical Quarterly,* 37 (October, 1933), 118-119; Ralph P. Bieber, ed., *Exploring Southwestern Trails, 1846-1854* (Glendale, 1938), 31-38; William A. Goetzmann, *Army Exploration in the American West, 1803-1863* (New Haven, 1959), 227-228, and John S. Ford, "Jack Hays in Texas," typescript, John Salmon Ford MMS, Box 2Q512, University of Texas Archives, 173-174.

21. Samuel Maverick, "Chihuahuan Expedition," typescript, Samuel Maverick MMS, Box 2R210, University of Texas Archives.

22. J. D. Affleck, "History of Jack C. Hays," typescript, J. D. Affleck MMS, Box 2Q402, University of Texas Archives, 748.

23. Greer, *Colonel Jack Hays,* 222.

24. William H. C. Whiting, "Whiting's Diary," *Publication of the Southern History Association,* 10 (1906), 83-85.

25. Goetzmann, *Army Exploration in the American West,* 228-230.

26. M. L. Crimmins, "Two Thousand Miles by Boat in the Rio Grande in 1850; with a Biographical Sketch of the Army Actions of Captain John Love," West Texas Historical and Scientific Society *Publication,* No. 5 (1933), 44-52.

27. Goetzmann, *Army Exploration in the American West,* 227.

28. John R. Bartlett, *Personal Narrative of Exploration and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua Connected with the United States and Mexican Boundary Commission during the Years 1850, 1851, 1852, and 1853* (New York, 1854) and Goetzmann, *Army Exploration of the American West,* Chapter 5, "The Boundary Survey," 153-208.

29. William H. Emory, *Report on the United States and Mexican Boundary Survey Made Under the Direction of the Secretary of the Interior,* 2 vols. in 3, U.S., House of Representatives, 34th Congress, 1st. Session (Washington, 1857), I, 80.

30. *Ibid.,* 81.

31. *Ibid.*

32. John E. Gregg, "The History of Presidio County," (unpublished MA Thesis, University of Texas, 1933), 283-286; Mrs. O. L. Shipman, *Taming the Big Bend: A History of the Extreme Western Portion of Texas from Fort Clark to El Paso* (Marfa, 1926), 26-27; Corning, *Baronial Forts of the Big Bend,* Chapter 3, "Don Milton, Lord of Three Manors," 43-64; Barry Scobee, "Don Milton Faver: Founder of a Kingdom," West Texas Historical and Scientific Society *Publication,* No. 19 (1963), 41-45 and Virginia Madison, *The Big Bend Country of Texas,* rev. ed. (New York, 1968), Chapter 7, "Longhorns to Herefords," 102-125 and Ch. 8 "Cattle are Kings," 126-134.

33. Robert M. Utley, "Longhorns of the Big Bend: A Special Report on the Early Cattle Industry of the Big Bend Country of Texas," typescript, U.S. Department of the Interior, National Parks Service, Region 3 (Santa Fe, 1962), 24-25.

34. Gregg, "The History of Presidio County," 281-282 and Utley, "Longhorns of the Big Bend," 16.

35. Miles, "Old Fort Leaton," 93-94; Carlysle G. Raht, *The Romance of Davis Mountains and Big Bend Country: A History,* edition Texanna (Odessa, 1963), Chapter 7, "1847–," 84-92; and Utley, "Longhorns of the Big Bend," 12-13.

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THE GEOLOGIC ENVIRONMENT OF COLORADO CANYON OF THE RIO GRANDE SOUTHEASTERN PRESIDIO COUNTY, TEXAS AND CHIHUAHUA, MEXICO

Dwight Deal

INTRODUCTION

Colorado Canyon of the Rio Grande is one of several major canyons cut by this river in the Big Bend region of Trans-Pecos Texas. It is a highly scenic place, providing an exciting but, under most normal river conditions, not terribly dangerous, canoe or raft trip. Because of the ease of public access to this reach of the Rio Grande, Colorado Canyon is one of the most popular float trips in the area. This report concerns not only Colorado Canyon proper but considers most of the immediate Rio Grande valley from the vicinity of Redford downstream to Lajitas, in neighboring Brewster County.

The Rio Grande has incised a valley through a series of large faulted blocks of alternating hard and soft volcanic strata, including ancient lava flows, welded volcanic ash deposits (welded tuffs), poorly consolidated volcanic ash deposits, and associated sedimentary material.

This report is prepared for the Natural Areas Survey, Center for Natural Resources and Environment, The University of Texas at Austin. There are three companion volumes in the series of reports prepared by the Natural Areas Survey that discuss areas in the immediate vicinity of Colorado Canyon: one each on the Bofecillos Mountains, Fresno Canyon, and the Solitario. The geological part of the Solitario report (Deal 1976a) describes in detail the older Paleozoic and Cretaceous sedimentary strata; the report on the Bofecillos Mountains (Deal 1976b) describes in detail the volcanic units built up during the eruptions of the Bofecillos Volcano, which had a central vent about 16 km (10 miles) north of Colorado Canyon, and the Fresno Canyon report (Deal 1976c) describes the area between the Bofecillos Volcano and the Solitario Uplift, including the spectacular Madrid Falls in Chorro Canyon and Mexicano Falls in Arroyo Segundo.

This report on Colorado Canyon of the Rio Grande will emphasize what is known about the most recent geologic history of this area: the development of the modern Rio Grande drainage system. Most of the rocks that are exposed along this reach of the Rio Grande are described in more detail in the companion volume on the Bofecillos Mountains (Deal 1976b).

The basic resource document describing the geology along this stretch of the Rio Grande is a Ph.D. dissertation by John McKnight (1968), a condensed version of which is presented with a geologic map in a publication by the Texas Bureau of Economic Geology (McKnight 1970). I have drawn heavily upon McKnight's work in preparing this report and walked most of the canyons and the mesa country in the summer and fall of 1975 with the Natural Areas Survey field parties. In addition, I have a long-term interest in the Quaternary history of the southwestern United States, in particular the history of the Rio Grande and the Rio Conchos. Recent investigations by a number of workers in the Rio Grande valley upstream from El Paso have shed considerable light on the problem, but much is still unknown about the timing and sequence of events involved with the origin and development of the course of the modern Rio Grande and Rio Conchos. Much of that story, as presented later in this report, is unproven and expresses my current interpretations which, although based on the available information, are colored by my feelings about the Late Tertiary and Quaternary history of western North America. My ultimate goal is to understand this river system, and I hope that the thoughts presented here will at least provide some springboard for future discussions.

This report is designed to provide a comprehensive overview of the geology of the Colorado Canyon area to be used by both geologists and interested laymen. Although I have attempted to reduce geologic jargon to a minimum, some users may find it helpful to refer to the *Glossary of Geology* (Gary and others 1972). Those interested in a more detailed description of the geology are referred to McKnight (1968) or Deal (1976b). Colored copies of McKnight's (1970) geologic map and geologic cross-sections of the Bofecillos Mountains are attached to some copies of this report; additional copies are available directly from the Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas 78712.

PREVIOUS AND RELATED WORK

The 1857 Mexico-U.S. Boundary Survey headed by Emory passed through this area. One of the members of that survey was C. C. Parry (1857), who wrote the first report on the geology of the Bofecillos Mountains. Parry's report was of necessity a reconnaissance and concentrated on describing the striking physiography along the course of the Rio Grande, including the general vicinity of Colorado Canyon. He described the bolson and pediment development in the basins along the river and the igneous rocks which are exposed in the canyons.

Kimball (1869) traveled southeastward through Presidio as part of a reconnaissance through west Texas and northern Chihuahua. He crossed the Rio Grande Valley and explored the drainage of the Rio Conchos, describing fossils that demonstrated that much of the limestone in the area was of Cretaceous age. He noted the overlying volcanic ash falls and lava flows, which are now known to be of Tertiary age, incorrectly considering them to be Cretaceous and inferring a metamorphic, rather than a volcanic, origin for them.

In the late 19th Century, the discovery and development of mercury deposits along the Terlingua Monocline brought many geologists into the area. A good summary of the development of the mercury (cinnabar) resources in the Terlingua District, east of Colorado Canyon study area, is presented by Daugherty (1972, *in* Deal 1976c: Appendix 3). The early history of exploitation, distribution, and origin of the deposits is described in reports by Blake (1895), Turner (1900, 1906), Spalding (1901), B. F. Hill and Phillips (1902), R. T. Hill (1902), B. F. Hill (1903), Phillips (1905), Kirk (1905), and Udden (1907b, 1918). Udden's 1907 "Sketch of the Geology of the Chisos Country" was particularly significant to the study of the Bofecillos Mountains and Fresno Canyon area because it fitted the Terlingua District into the regional geologic setting. More detailed work by Ross (1935, 1937, 1941) and by Yates and Thompson (1959) further explain the geologic factors controlling ore implacement and additionally describe the regional stratigraphy and structure of the area.

The Solitario, 20 km northeast of Colorado Canyon, received some mention in mineral reports on the Terlingua District. Further information on the Bofecillos Mountains and on the Solitario are contained in companion reports by Deal (1976a, 1976b).

Maps and reports, mostly sponsored by the University of Texas Bureau of Economic Geology (Sellards and others 1933; Goldich and Elms 1949; Seward 1950; Erickson 1953; Lampert 1953; McCarthy 1953; Moon 1953; Rix 1953; Zinn 1953; Dietrich 1954, 1965, 1966; McAnualty 1955; Amsbury 1958, and Ramsey 1951) carried Tertiary volcanic stratigraphy from the north and northwest, providing the basis for McKnight's (1968) work on the Bofecillos Volcano itself.

A geologic report on the Big Bend National Park, immediately southeast of the area (Maxwell and others 1967), is a detailed study of the geologic history of that area and allows McKnight (1968) to relate the events of the Bofecillos Volcano to the events occurring within the National Park.

The International Boundary and Water Commission (1955) prepared a series of geologic strip maps at a scale of 1:50,000 along the Rio Grande, extending upstream from Del Rio to a point about six km upstream from Lajitas near the mouth of Fresno Canyon in the southeastern extremities of the Bofecillos Mountains. Arenal (1964) made a geologic reconnaissance map on the Mexican side of Colorado Canyon in a study of coal and lignite deposits in rocks of Upper Cretaceous age. J. A. Wilson and his students (1952, *in* Maxwell and others 1967) have collected vertebrate fossils from locations outside but near the Bofecillos Mountains. Twiss and DeFord (1967) published some potassium-argon age dates from the rimrock country northwest of the study area, and Wilson and others (1968) compiled more detailed information on the stratigraphic succession, potassium-argon dates, and vertebrate faunas of the same area.

Considerable work has been done in the last decade on the Quaternary sedimentation and erosional history of the Rio Grande upstream from El Paso. These studies are very important in an understanding of the events occurring in the Big Bend area. The Quaternary events and deposits, especially in the river valley area of Doña Ana County in New Mexico, have been described in considerable detail by Hawley (1965), Metcalf (1967), Ruhe (1967), Hawley and Kottlowski (1969), Gile and others (1970), Seager and Hawley (1973), Hunt (1974), Seager and others (1975), Hawley (1975), Seager (1975), and Chapin and Seager (1975). Earlier physiographic studies were by Fenneman (1931), Brand (1937), King (1937), and Thornbury (1965).

Belcher (1975b) conducted an extensive literature review and, documented by spotty field work, rejected the conclusions reached by most of today's field workers to resurrect assumptions that assign great antiquity to the Rio Grande-Rio Conchos system. The bibliography and previous work section in his Masters Thesis (Belcher 1975a) are useful references.

ACCESS

Paved State Highway 170 (the River Road) runs parallel to the Rio Grande through the study area. In most places it is within a kilometer of the river itself and leaves the immediate valley of the Rio Grande only in the vicinity of Colorado Canyon, where it is separated from the Rio Grande by Colorado Mesa. Vehicular access is largely limited to the paved highway; even with a 4-wheel-drive vehicle it is possible to drive only a short distance from the pavement.

PHYSIOGRAPHY

The topography on the United States side of the river is shown on five fairly recent (1971) U.S. Geological Survey 7½-minute topographic quadrangle maps: Agua Adrentro Mountain, Lajitas, Redford, Redford Southeast, and Santana Mesa. A topographic map with a scale of approximately two miles to the inch with 100-ft contour intervals was prepared by McKnight (1968: Fig. 18) and is included in this report as Figure 1. He compiled this map from U.S. Geological Survey 1:250,000 and 1:125,000 topographic maps for the United States side of the river and sketched the topography and geology south of the river from aerial photographs with topographic control taken from a U.S. Coast and Geodetic Survey aeronautical chart of a scale of 1:500,000. The contours shown in Mexico outline the major land forms fairly accurately, but the elevations are generalizations and are much less accurate than those shown on the north side of the river. A topographic strip map at a scale of approximately 2000 ft to the inch and 20 ft contour intervals, accompanies this report. That map shows the topography in the immediate vicinity of the river and is compiled from maps made in 1949 for a dam site and reservoir study by the International Boundary and Water Commission.

The Colorado Canyon area is within the Basin and Range physiographic province of the southwestern United States and exhibits desert landforms that are characteristic of the region as a whole. McKnight (1968: Fig. 4) prepared a diagram showing the physiographic subdivisions of the Bofecillos Mountains area, including the Colorado Canyon study area, that is reproduced here as Figure 2. The dominant feature in the central part of Figure 2 is the Bofecillos Volcano, erupting from a vent approximately 16 km (10 miles) north of Colorado Canyon. Lavas and volcanic ash from this volcano were spread across the study area. After the major pulse of activity, numerous northwest-southeast trending vertical faults cut the southern part of the Bofecillos Volcano into numerous fault-bounded blocks (Fig. 3; McKnight 1968: Fig. 17). These blocks are bounded by nearly vertical faults; the relatively down-dropped blocks are called "grabens," while the dominantly up-thrown blocks are called "horsts." The present course of the Rio Grande through the Colorado Canyon study area is approximately along the axis of the compound graben system with generally up-stepping blocks both to the northeast into the United States and to the southwest into Mexico.

The lowest of the down-dropped blocks received sediments after faulting but prior to the development of the Rio Grande drainage through the area. After the filling of the lowest grabens with valley-fill sediments (mostly sand and gravel), the Rio Grande integrated its drainage across the area, incising the previously isolated basins and creating a series of breached bolsons (mountain-ringed desert basins). The fault blocks constitute a fault-block zone, forming an extensive broken area on either side of the Rio Grande valley. High-standing blocks of relatively resistant Tertiary volcanic rocks are exposed at the surface.

Although scarps are modified by differential erosion, the relief seen on them reflects the original movement along the faults. Major streams are deeply incised and poorly adjusted to fault trends, most of which were buried beneath sedimentary material at the time the Rio Grande first established its course through the area. Many cliffs and canyon walls are 100-200 m high, and several cliffs are more than 400 m (1200 ft) high. Elevations exceed 1500 m (5000 ft) above sea level in the mountains both north and south of the river. The river descends from an elevation of approximately 760 m (2500 ft) near Redford to about 700 m (2300 ft) at Lajitas. The average river gradient is approximately 1.1 m per km (6.1 ft per mile) along this stretch and approximately 1.2 m per km (6.7 ft per mile) through the 10-km- (6-mile-) long Colorado Canyon. The sheer walls of Colorado Canyon itself rise 200-800 ft above the river.

A remarkable side canyon, Closed Canyon (also locally known as Poquito Cañon or Lost Canyon), is cut through Colorado Mesa by a tributary to the Rio Grande from the north. This canyon is approximately one km long and is a very narrow, steep, and spectacular gash (Fig. 4). The average gradient through Closed Canyon is approximately 85 m per km (450 ft per mile).

CLIMATE

No climatic records have been kept in the Colorado Canyon area itself. A U.S. Weather Bureau station was in operation in Presidio from 1957 until 1969, and Dietrich (1965:14-23) presents a fairly elaborate discussion on both regional and local climate of the Presidio and Bofecillos Mountains area to the north and west. He goes into a rather detailed discussion of the classification of climate and analyzes what data is available for this part of Trans-Pecos Texas. His conclusions are summarized in the companion volumes on the Bofecillos Mountains and Fresno Canyon areas (Deal 1976b, 1976c). The Colorado Canyon study

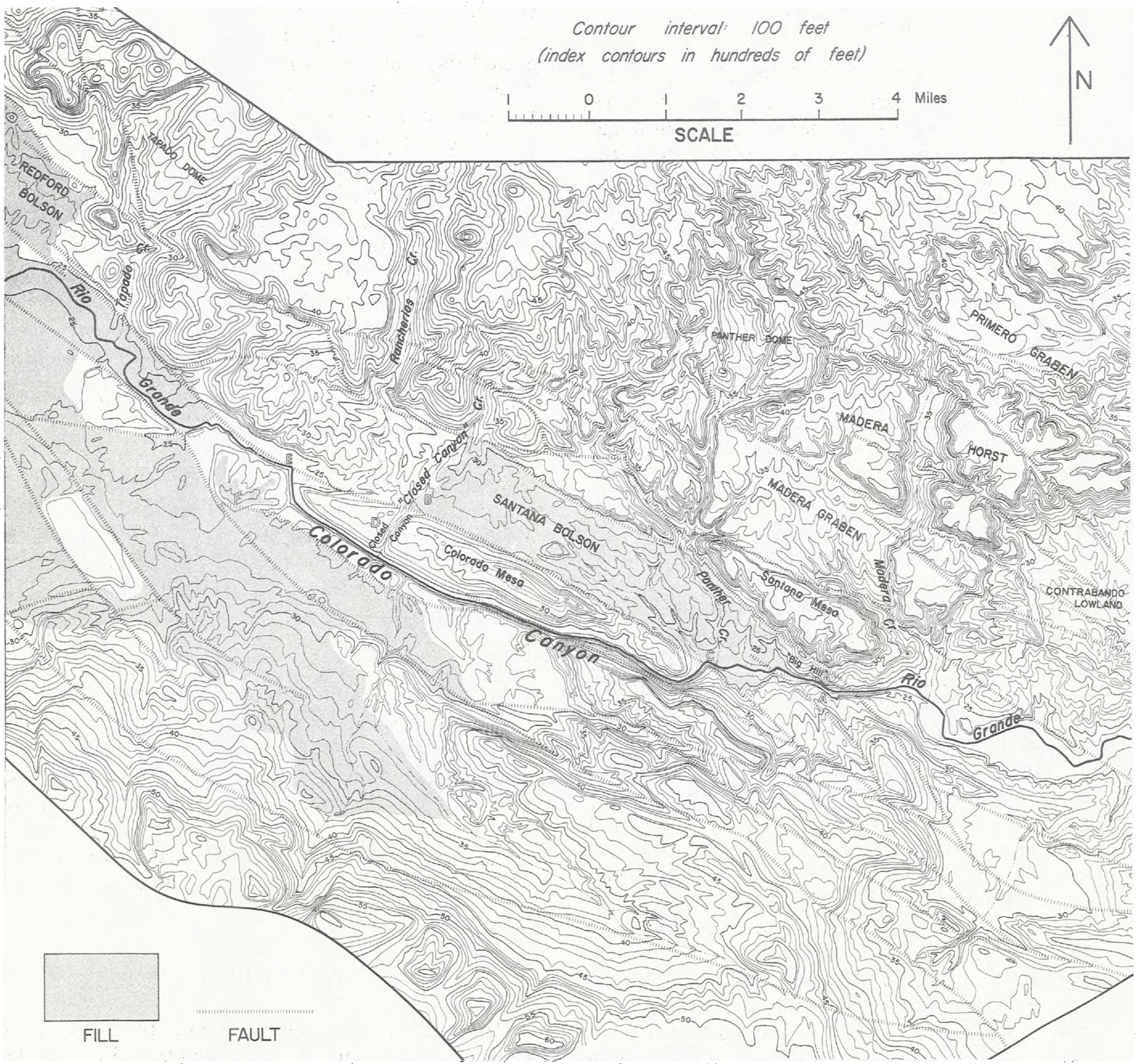

FIGURE 1
Topography, faults, and preserved fill along the Colorado Canyon segment of Rio Grande (From McKnight 1968: Fig. 18)

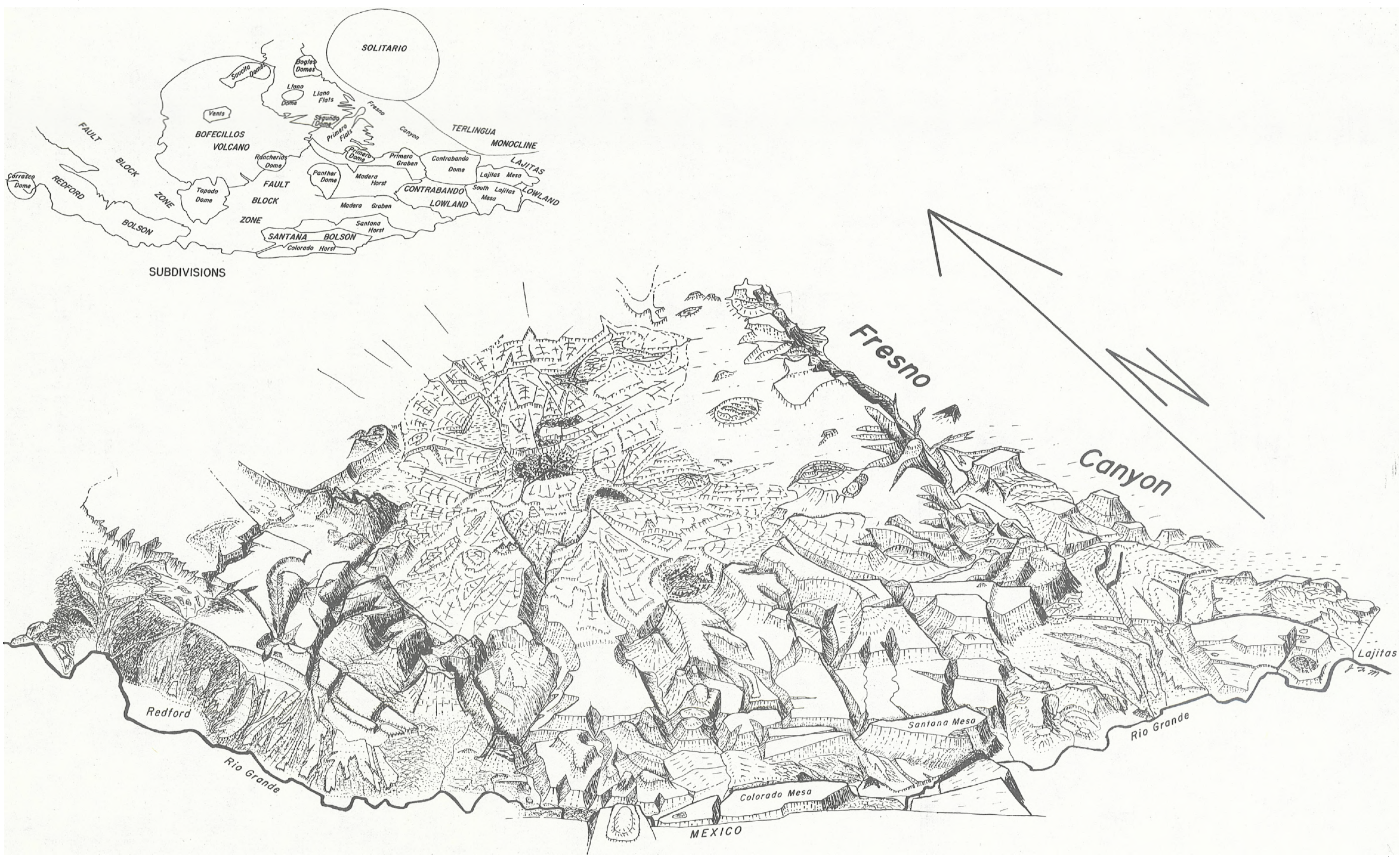

FIGURE 2
Physiographic diagram of the Bofecillos Mountains
(From McKnight 1968: Fig. 4)

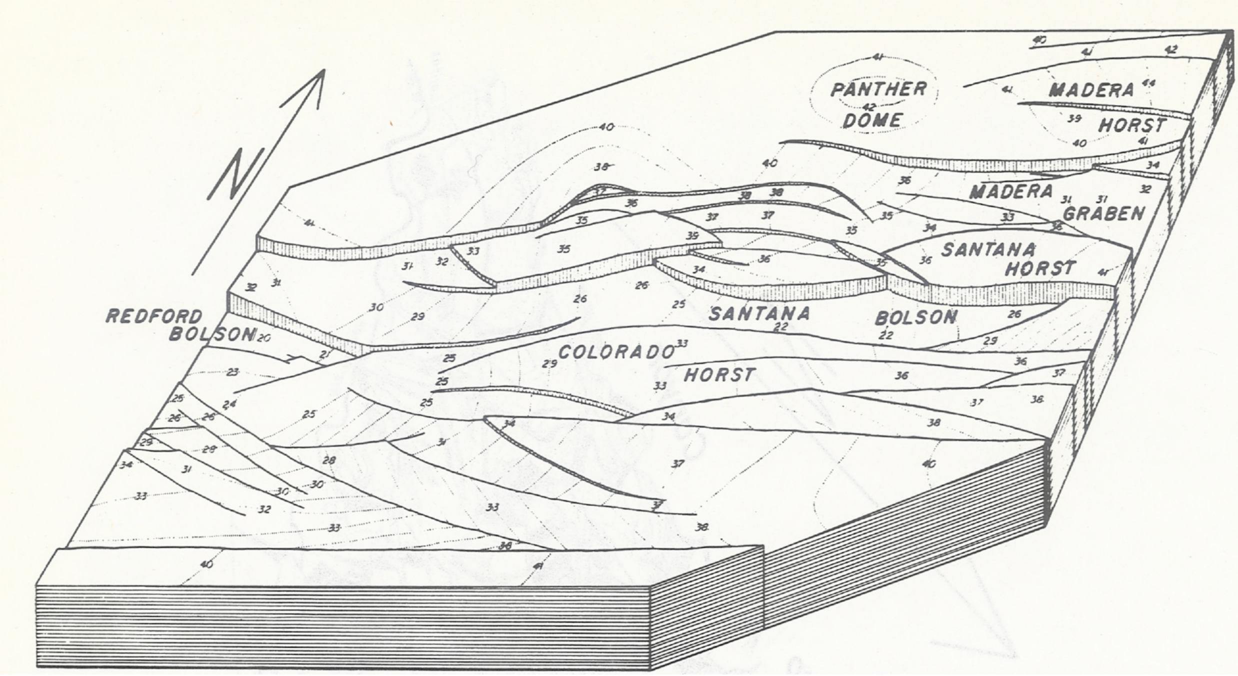

FIGURE 3

Pattern of jostled fault blocks along middle segment of Rio Grande. Approximate structure contours are drawn at the base of the fill. The diagram covers about 20 kilometers east-west. (From McKnight 1968: Fig. 17)

area has a typical Chihuahuan Desert climate, receiving precipitation on the order of 20-25 cm (8-10 in) per year.

The presence of perennial surface water in the canyon profoundly modifies the microclimate in the immediate vicinity of the river. Dietrich (1965:22-23) presents a good discussion of this effect:

> The U.S. Weather Bureau collects temperature data from a uniform height above the surface site selected to give data representative of large areas. These data accurately reflect the macroclimate, the climate above a thin boundary layer of air above the surface. The microclimate, the climate within the boundary layer a few inches to a few feet thick, is highly variable.
>
> Where the macroclimate is near the borderline separating steppe and desert climates, the effects of factors that modify the microclimate are dramatic. Surface attitude and texture are two important factors that affect surface temperature, and therefore the microclimate. South-facing slopes, more nearly normal to the sun's rays than north-facing slopes, or the floors of narrow-walled canyons, receive more abundant energy per unit area and are a little hotter and drier. Soil on an open surface is hotter and drier than the soil in pockets between large boulders because the boulders shield the small pockets from direct solar radiation during part of the day. Because of these small differences, grass grows on north-facing or boulder-strewn surfaces at elevations where south-facing or open surfaces are barren. A tank, a spring, or flowing stream modifies the climate in a small area. Evaporation lowers the air temperature and increases the humidity in the immediate vicinity of the water.

GEOLOGIC HISTORY

Introduction

The geologic framework of the Big Bend area of Trans-Pecos Texas is complex. Intensely folded and faulted ancient sedimentary rocks of Paleozoic age lie beneath the surface in much of the area but are exposed only in the Solitario Uplift and in the Marathon Basin northeast of Colorado Canyon. These old rocks are now buried beneath a blanket of younger limestones, typically exposed on the Edwards Plateau and in the canyons of Big Bend National Park. These limestones and associated sediments are of Cretaceous age and are in turn buried beneath a complex sequence of lava flows, volcanic ash, and associated continental sedimentary materials. The rocks exposed at the surface in the Colorado Canyon study area (McKnight 1970: geologic map) are the young volcanic and sedimentary materials. Most of the cliff-forming units were erupted from vents either in the Bofecillos Mountains to the north or from vents in Mexico, south of Colorado Canyon. Some material was probably ejected from vents in the Chisos Mountains to the east.

In this report we are primarily concerned with the most recent geologic history of the area, the story of the Rio Grande. The details of the older geologic events are described in companion volumes prepared by the Natural Areas Survey. The older sedimentary history is best described in the report on the Solitario

(Deal 1976a), the volcanic rocks and the growth of the Bofecillos Volcano (centered 16 km north of Colorado Canyon) are described in the report on the Bofecillos Mountains (Deal 1976b), the ground-water resources in the reports on the Bofecillos Mountains and Fresno Canyon (Deal 1976b, 1976c), and the history of the development of the mercury-ore deposits in the Terlingua mining district to the east in the report on Fresno Canyon (Deal 1976c).

At the end of the main episode of volcanic activity, the study area looked much like the desert Basin and Range physiographic province that is typical of the southwestern United States. Characteristically, the Basin and Range province consists of isolated mountain ranges surrounding desert basins that have no through-flowing drainage to the sea. A general uplift of western North America occurred in the Late Tertiary. The ancestral Rio Conchos and Rio Grande, fed by increased precipitation in their now more elevated headwaters, probably began then to fill the previously dry basins near their headwaters with temporary lakes. (The Rio Conchos heads southwest of the study area in the Sierra Madre Occidental of Mexico, southwest of Chihuahua City, and the Rio Grande heads in the mountains of northern New Mexico and southern Colorado.) When those rivers filled their upper basins with lakes, the water overflowed and spilled downstream into progressively lower basins. The older upstream lake basins began to be excavated by the ancestral Rio Grande and Rio Conchos when the drainage spilled into a lower basin. Each time the drainage overflowed into another downstream basin, a wave of renewed downcutting probably progressed upstream into the previously-integrated basins.

Eventually one of the two ancestral rivers spilled into the Presidio bolson. It is likely the Rio Conchos, fed by rainfall in the mountains southwest of Chihuahua, Mexico, arrived in the Presidio area before the Rio Grande, which was fed largely by snowmelt to the north in the southern Rocky Mountains. The ancestral drainage of the Rio Grande (or Rio Conchos) probably proceeded to fill the Presidio bolson with a lake which then overflowed across the divide southeast of Redford, now the location of Colorado Canyon, into a lower basin. In this way the ancestral river probably worked its way eastward until it finally overflowed into the headwaters of some tributary of the ancestral lower Rio Grande (probably what is now known as the Pecos River), somewhere east of what is now Big Bend National Park. At this time the ancestral Rio Grande (or Rio Conchos) established an integrated drainage to the Gulf of Mexico. The upstream portions of the river in the Big Bend region then began to downcut more rapidly. Tributaries to the Rio Grande, such as Fresno Creek and the other tributary drainages in the Colorado Canyon area, downcut as the main canyons of the Rio Grande were incised.

The initial course of the Rio Grande was established across the floors of sandy, silty, and gravelly basins. Meandering stream patterns develop when a river is cutting through and shifting the unconsolidated sediments of its own floodplain, and some elements of todays meandering pattern of the Rio Grande may have begun to develop at that time. Initial incision began by removing some of the unconsolidated basin-filling deposits, but later the river started to cut into the older rocks that underlay the basins. As the main channel began to saw into the resistant, underlying rocks, canyons began to be formed and the broadly meandering pattern of the ancestrial river was trapped and preserved as the meandering canyons we see today.

With increased downcutting along the Rio Grande and the incision of Colorado Canyon, the tributary drainages also began to cut canyons: Fresno Canyon, Panther Canyon (Cañon Leon), Closed Canyon (Lost Canyon or Poquito Cañon), Rancherias Canyon, Tapado Canyon (Oso Cañon), Las Burras Cañon, and the other canyons draining the Solitario, the Bofecillos Mountains, and the mountain ranges to the south in Mexico.

The only way a perennial river can flow through the arid basins of the Chihuahuan Desert is to be fed by dependable rain and snowfall in higher mountains outside of the desert itself. Intense desert thunderstorms additionally cause the Rio Grande and Rio Conchos to swell catastrophically and to do a tremendous amount of erosional work in brief periods during the summer and fall.

The tributary canyons undergo significant erosion only during the brief but intensive runoff from local thunderstorms. This, coupled with the fact that the drainage basins of the tributary canyons are much smaller than that of the main stream during times of rapid downcutting by the Rio Grande. Closed Canyon (Fig. 4) is an excellent example of a tributary canyon trying to erosionally "catch up" with the main drainage.

The Colorado Canyon reach of the Rio Grande has long been difficult to traverse. Colorado Canyon itself is incised into the welded and very resistant Santana Tuff, and immediately downstream from Colorado Canyon is the place known locally as Big Hill. Here the Rio Grande has incised a short but very steep-walled canyon through a resistant igneous intrusion. Until the fairly recent construction of Texas Ranch Road 170 it was impossible to traverse east or west across the vicinity of Big Hill in a vehicle. Dirt roads extended downstream to the vicinity of Colorado Canyon from Presidio and Redford and upstream from Terlingua and Lajitas, but Big Hill remained a barrier to vehicles. The ruggedness of the terrain that created this barrier to travel is also responsible for some of the impressive scenery of the region. The scenic beauty of the area is inhanced by the fact that the streams that drain the southern side of the Bofecillos Mountains contain numerous seeps, springs, and waterfalls a short distance upstream from their junction with the Rio Grande. The groundwater conditions responsible for these springs and seeps is discussed in more detail in the companion volume on the Bofecillos Mountains (Deal 1976b).

Paleozoic Stratigraphy and Mountain Building

The older rocks known to underlie the Colorado Canyon area are those of Lower Paleozoic age. These rocks are exposed within the Solitario Dome just to the northeast of Colorado Canyon and are described in more detail in the companion volume on the Solitario (Deal 1976a) and in the works of Herrin (1958), Wilson (1954), West Texas Geologic Society Field Guidebooks (1965, 1972), and Corry (1972). Most were deposited beneath ocean waters.

Briefly, from oldest to youngest, the Paleozoic section consists of the following: The Dagger Flat Formation (sandstone) of Cambrian age; the Marathon Formation (black siliceous shale, sandstone, sandy limestone, dark chert, and blue limestone), the Fort Peña Formation (limestone, sandy limestones, and cherts), the Woods Hollow Shale (fine-grained shale with some flaggy sandstones and siltstones), and the Maravillas Chert (black bedded chert with some limestone lenses and some intraformational conglomerates), all of the Ordovician age; and the Caballos Novaculite (white chert) of Divonian-Mississippian age. The two chert units (the Maravillas Chert and the Caballos Novaculite) are prominent ridge-formers within the Solitario. The total thickness of the Paleozoic section exposed in the Solitario is about 2600 m.

A major series of mountain-building events followed the deposition of the Paleozoic rocks in Late Pennsylvanian-Early Permian time (Deal 1976a; Flawn and others 1961:188). These events were part of what is called the Ouachita Orogeny, a major and continuous band of folding that extended over much of the southern United States, comparable in age and type to the Appalachian Mountain structures of the eastern United States. The axis of the Ouachita fold belt in the Solitario-Marathon region extends northeast to southwest with thrusting and compression from the southeast to the northwest. These intensely folded, distorted, and faulted rocks must certainly underlie the Fresno Canyon area.

Herrin (1958:73) found some indirect evidence indicating that some rocks of Permain age may have been deposited in this general area. He found Permian fossils in small boulders of limestone included in a tuffaceous conglomerate in Tertiary volcanic rocks exposed in the southern part of the Solitario. If Permian rocks were deposited in the vicinity of the study area, they were removed by erosion prior to the deposition of the Cretaceous limestones. Everywhere in southern Brewster and Presidio Counties the Cretaceous rocks lie directly on the intensely deformed Paleozoic sediments.

Cretaceous Stratigraphy and Mountain Building

Following the Ouachita mountain-building period, Trans-Pecos Texas experienced a considerable time of erosion. The area was above sea level, and erosion reduced what must have been a magnificent mountain range to a nearly flat, relatively featureless plain. In early Cretaceous time (about 145 million years ago) the southeastern Presidio County area was submerged once again beneath ocean waters, and a sequence of massive limestones was deposited in a northward extension of the Mexican Geosyncline.

The Cretaceous rocks are described in more detail in the companion volume on Fresno Canyon (Deal 1976c) and can conveniently be considered as consisting of two major subdivisions. The lower subdivision begins with a basal conglomerate (the Shutup Conglomerate), followed by a seqence dominated by massive limestones, which, from oldest (basal) to youngest (upper), are the: Yucca Formation, Glen Rose Formation, Telephone Canyon Formation, Del Carmen Limestone, Sue Peaks Formation, and Santa Elena Limestone. The massive cliffs exposed around the Solitario and in the canyons of Big Bend National Park are formed by the Glen Rose, Del Carmen, and Santa Elena Limestones. Overlying this is a sequence of alternating hard and soft units that include the uppermost Lower Cretaceous beds (the Del Rio Clay and the Buda Limestone) and the Upper Crataceous rocks (Boquillas, Penn, and Aguja Formations).

The massive cliff-forming units of the Lower Cretaceous are not exposed in the Colorado Canyon study area but must underlie it. Upper Cretaceous rocks are exposed east of Big Hill along Fresno Creek and in the vicinity of Lajitas and must also underlie Colorado Canyon.

Approximately 1.2 km of thick, flat-lying limestones were deposited on top of the intensely deformed and eroded Paleozoic rocks. Following their deposition, the main mountain-building episode of the North American Cordillera, known as the Lara-

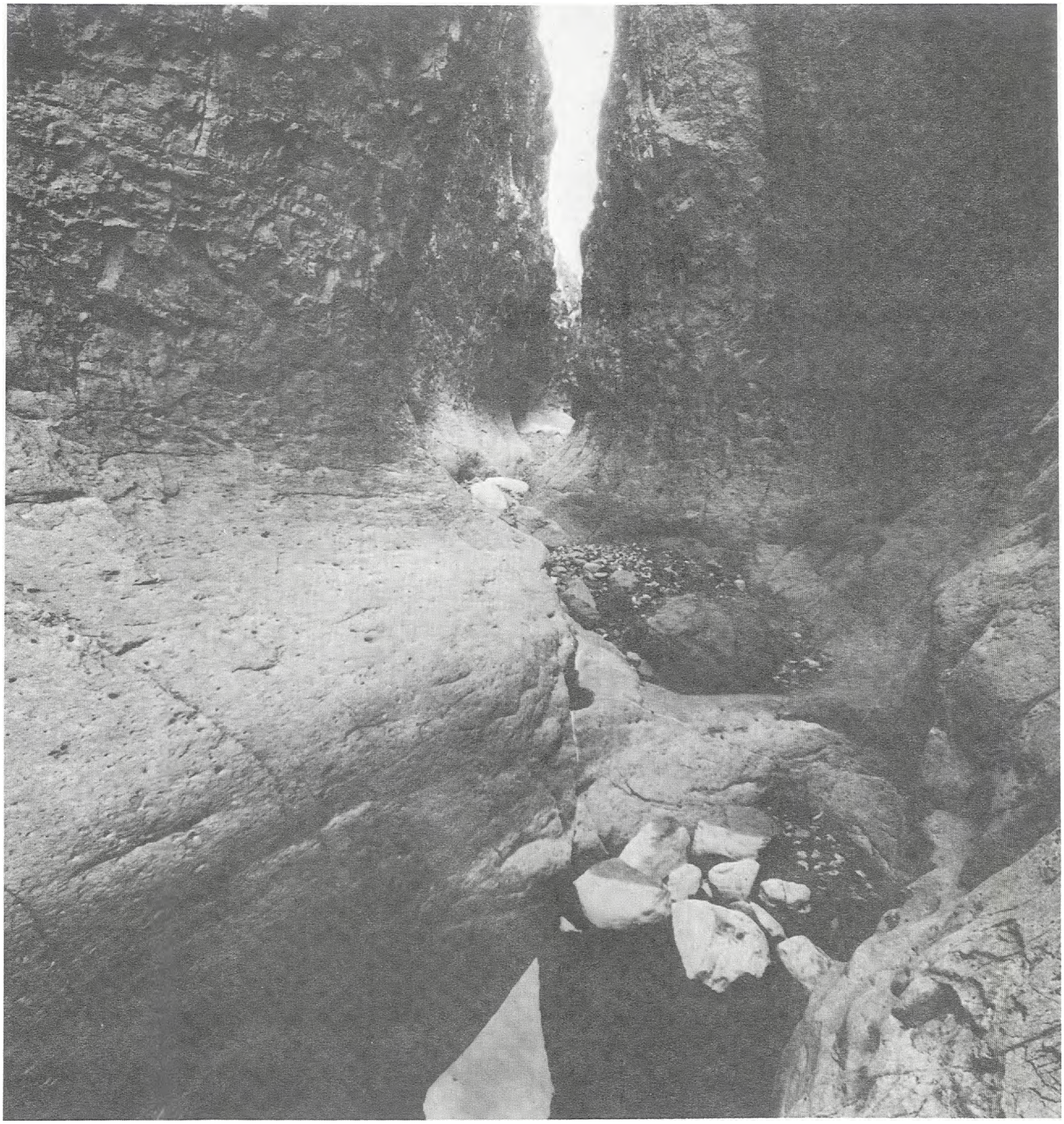

FIGURE 4

Closed Canyon: a flood-flushed tributary to Colorado Canyon of the Rio Grande.
(Photo by Reagan Bradshaw)

mide Orogeny, occurred. It is evidenced in Trans-Pecos Texas by the creation of folded uplifts and associated faulting. The Laramide mountain-building period began in Late Cretaceous time and continued into the early Tertiary.

Doming of The Solitario

In the vicinity of the Solitario, the Laramide was followed by a series of igneous intrusions, in turn followed by a series of volcanic eruptions which buried the older limestones beneath a sequence of ash deposits and lava flows.

The first indication of volcanic activity in southeastern Presidio County was an intrusion of magma into the base of the Cretaceous limestone sequence in early to middle Tertiary [probably Eocene or Miocene time (about 20 to 45 million years ago) (Fred McDowell: oral communication March 1976)]. Then as the intrusive activity progressed, the Solitario Dome was formed. After the doming of the Solitario and prior to the deposition of the Tertiary volcanic rocks in the area, the structure known as the Terlingua-Solitario Monocline (Maxwell and others 1967) was formed. This structure extends northwestward into the southeastern edge of the Fresno Canyon area, where the trend turns northward and merges with the Solitario structure. The origin of this structure is discussed in more detail in the companion volume on Fresno Canyon (Deal 1976c: Appendix 2).

Tertiary Volcanic Stratigraphy

Laramide mountain building led into a sequence of Tertiary volcanic events that affected most of southern and western United States and northern Mexico. In the Big Bend area of Trans-Pecos Texas, these events were mostly of Eocene and Oligocene age (20-60 million years ago).

The details of the volcanic stratigraphy of West Texas are extremely complicated; there are many individual beds that were erupted from a number of distinctly isolated volcanic centers. There were several major eruptive centers in the Big Bend area and many minor ones. Major centers include the Chisos Mountains in Big Bend National Park, the Davis Mountains, Chinati Peak, and several ranges south of the Rio Grande in Mexico. The Bofecillos Volcano was a relatively small and localized eruptive center, located approximately 16 km (10 miles) north of the Colorado Canyon study area and active toward the close of the main volcanic period.

The Tertiary volcanic sequence in the Colorado Canyon area was described and mapped in detail by McKnight (1968, 1970) and is described in much greater detail in the companion volume on the Bofecillos Mountains (Deal 1976b). Briefly, from oldest to youngest, the Tertiary units consist of the following formations: Jeff Conglomerate, Chisos Formation, Mitchell Mesa Tuff, Fresno Formation, Santana Tuff, and Rawls Formation.

Jeff Conglomerate

Prior to the eruption of the main volcanic phase, a sedimentary conglomerate consisting of well-rounded cobbles or boulders of limestone was deposited on top of the uppermost Cretaceous sedimentary strata (McKnight 1968: 25-31; Deal 1976c: Appendix 1). This unit is exposed along Fresno Creek and in the Contrabando Lowland east of Big Hill (McKnight 1970: geologic map).

Chisos Formation

The volcanic rocks that overlie the Jeff Conglomerate in the Colorado Canyon area are predominantly light-colored, soft, volcanic ash deposits and two resistant lava flows of the Chisos Formation. The soft light-colored units are composed largely of volcanic ash falls (tuff), associated stream deposits (conglomerates and sandstones), mud flows, lake deposits (nonmarine limestone), and wind-blown ash, dust, and sand. The white tuffs and sedimentary rock of the Chisos Formation are well exposed in a road cut on State Highway 170 about 1 km southeast of the Madera Canyon bridge. In this vicinity the tuff commonly erodes to scenic "hoodoos" or "demoiselles."

The type locality of the Chisos Formation is in Big Bend National Park (Maxwell and others 1967), where it includes undifferentiated tuff and sedimentary rock and five formally named members, four of which are resistant lava flows. From oldest to youngest, they are the: Alamo Creek Basalt, Ash Spring Basalt, Bee Mountain Basalt, Mule Ear Spring Tuff, and Tule Mountain Trachyandesite. With the exception of the Ash Spring Basalt, all of these extend into the Bofecillos Mountains area (McKnight 1968: 32).

Alamo Creek Basalt.—The Alamo Creek Basalt is exposed on the south face of Lajitas Mesa east of the study area and due north of the town of Lajitas. There it is a single flow about 28 m (90 ft.) thick (McKnight 1968: Measured Section 1 and p. 39; this report, Appendix 1). It thins to the west and is absent on the west side of Fresno Creek.

Bee Mountain Basalt.—The type locality of the Bee Mountain Basalt member is on the west side of Bee Mountain in Big Bend National Park where Maxwell and others (1967) named and described it. McKnight (1968: 41-45; 1970: geologic map) notes that it is exposed in Lajitas Mesa and South Lajitas Mesa and in the hills within 1.5 km (1 mile) of the Rio Grande between Fresno Creek and Madera Canyon in the eastern edge of the Colorado Canyon study area. It is exposed almost continuously along the Rio Grande on the Mexican side of the river between Lajitas and Madera Canyon but is not present north or west of the Contrabando Lowland. McKnight continues:

> It probably pinches out within a few miles north of the Rio Grande and within a mile west of Madera Canyon.
>
> The Bee Mountain Basalt generally thins westward but thickness varies locally by as much as 100 feet because of relief on the surface over which it spread. In Lajitas Mesa and north of Lajitas it is a maximum 250 feet thick; in the cliff east of Contrabando Creek, 200 feet; 2 miles east of Santana Mesa, 100 feet. Outcrops to the west are sporadic; probably the flow followed preexisting stream valleys, but did not cover the interfluves.
>
> A representative section of the Bee Mountain Basalt is immediately north of Texas Route 170 near Lajitas. At this place the unit crops out continuously for several hundred feet across the southeast face of Lajitas Mesa; it is between 150 and 220 feet thick as a result of relief on the base.

McKnight (1968: 41-45) continues with a detailed description of the unit. It consists of both porous and nonporous basalt that is a very fine-grained black rock that weathers red-brown to yellow-brown on the surface. It probably originated as a single lava flow.

Mule Ear Spring Tuff.—The type locality of the Mule Ear Spring Tuff member of the Chisos Formation is at Mule Ear Spring in Big Bend National Park. It extends into the Bofecillos Mountains and Colorado Canyon area as a single ash flow of non-welded to thoroughly-welded tuff. Exposures are rare, however, because slopes are generally covered by slump blocks and landslide material from the overlying Tule Mountain member. McKnight (1968: 45-50) describes this rock in detail and discusses its occurrence in the Bofecillos Mountains area (Colorado Canyon is along the south margin of his map area) as follows:

> It crops out on the southeastern part of the map and in several breached domes where its stratigraphic interval is exposed. The member does not crop out in Fresno Canyon north of its pinchout near Rincon Mountain or in the Llano, Saucita, and Carrasco Domes. It is present to the southeast in the Big Bend Park and it crops out in the Rio Grande Valley in Mexico at least as far west as the Santana Bolson and probably as far west at Redford. It does not crop out in the quadrangles north of the Bofecillos Mountains area. Thus, it probably pinches out south of a line due west from Rincon Mountain and against the Solitario Dome and Terlingua Monocline from the south and east.
>
> The Tule Mountain trachyandesite porphyry is a cliff-forming lava flow that is normally 200 to 300 feet thick; it is thickest on the northeast slope of Santana Mesa, where Dietrich and Maxwell measured 350 feet.

Extensive exposures occur just north of State Highway 170, east of Big Hill between Madera Creek and Fresno Creek. An exposure in the fault block on the southeastern end of Colorado Mesa forms the cliffs at river level along the lower part of Colorado Canyon (McKnight 1970: geologic map). Other outcrops occur in the northwestern part of the Colorado Canyon study area in Tapado Canyon, several kilometers above the junction of Tapado Creek and the Rio Grande. The Tule Mountain member is probably a single flow.

Mitchell Mesa Tuff

The Mitchell Mesa Tuff overlies the Chisos beds. It is a distinctive and interesting rock unit which usually forms a very resistant layer that the nongeologist would probably mistake for a solidified lava flow. It is not, however, an ancient lava flow but originated from what was either a single, violent eruption or a series of closely-related violent eruptions of large quantities of very hot volcanic ash. The particles of ash were so hot when they came to rest that in most places they fused together and "welded" themselves into this very hard and resistant unit. A deposit of this type is referred to as an "ignimbrite" or "welded tuff" and is about the closest thing to "instant rock" that one can find in the geologic record. Most sedimentary rock units characteristically were deposited over a span of millions of years. In contrast, ignimbrites usually record a single event or a series of events very closely spaced in time. The Mule Ear Spring Tuff in the underlying Chisos Formation and the Santana Tuff, overlying the Fresno Formation, are similar deposits. A more detailed description of the eruptive mechanism responsible for these unusual units is given in the companion volume on the Bofecillos Mountains (Deal 1976b).

The top of the Mitchell Mesa Tuff is one of the most useful horizons for the stratigraphic correlation of the volcanic rocks in the Big Bend region of Texas. Not only does it form a hard, resistant, and distinctive unit, it covers an immense area. Known occurrences extend from the area of Big Bend Park northward to the Davis Mountains (north of Alpine) and westward (where it is called the Brite Ignimbrite) to the rimrock country south of Van Horn. Dietrich (1965) estimates a minimum areal extent of 4 million hectares (2500 square miles) in the United States, and Haenggi (1966) estimates a minimum of an additional 1 million hectares (700 square miles) in Mexico west of Presidio.

McKnight (1968: 57) describes the Mitchell Mesa as a cliff-forming, ash-flow tuff that lies either directly above the Tule Mountain Member of the Chisos Formation or above as much as 6 m (20 ft) of Chisos Tuff. The Mitchell Mesa usually ranges between 6 and 11 m (20-35 ft) in thickness, with a maximum thickness of about 15 m (50 ft) in the Bofecillos Mountains area, which includes Colorado Canyon. It thins markedly in the southeastern part of the study area; at two outcrops on South Lajitas Mesa it is 1.5 m (5 ft) and 0.6 m (2 ft) thick. On the northeastern end of Santana Mesa it is no more than about 3 m (10 ft) thick. It is exposed in the cliffs north of the Teepees, the Texas Highway Department rest area just east of Big Hill, in the eastern part of the study area. It also occurs on several summits along the ridge extending southeastward from the southeast end of Colorado Mesa along the northern edge of the Rio Grande, above the cliff of Tule Mountain trachandesite porphyry at the river's edge. West of these occurrences, none of the Mitchell Mesa is exposed along the Rio Grande in the study area. It does occur in the lower portions of Tapado (Oso) Canyon a few kilometers upstream from its junction with the Rio Grande.

The Bofecillos Volcano

Both the Chisos Formation and the Mitchell Mesa Tuff were erupted from centers outside the Bofecillos Mountains-Colorado Canyon area. About the time the Mitchell Mesa event occurred, the initial stages of the eruption of the Bofecillos Volcano began. The eruptive center for the Bofecillos Volcano is a vent area approximately 16 km (10 miles) north of Colorado Canyon. Initial eruptions were of ash and lava which interfingered with some ash deposits that probably were ejected from other eruptive centers. As volcanic activity at the Bofecillos vent increased, a progressively more complex sequence of lava flows, ash falls, and associated sedimentary materials accumulated in the study area. Approximately halfway through the growth of the Bofecillos Volcano, another welded tuff unit, the Santana Tuff, probably erupted from a vent in Mexico south of Colorado Canyon, lapped onto the flank of the Bofecillos Volcano and the Solitario Uplift. Although this unit is not as widespread as the Mitchell Mesa Tuff, it is locally quite a useful key in interpreting the stratigraphic relationships of other, more localized volcanic deposits. The Santana Tuff is a distinctive unit in the field and is of major importance in the Colorado Canyon study area. It also conveniently separates the material erupted from the Bofecillos Volcano into upper and lower units.

By definition then, all the rocks between the top of the Mitchell Mesa Tuff and below the Santana Tuff are called the Fresno Formation, and all the Bofecillos volcanic rocks above the Santana Tuff are called the Rawls Formation.

Fresno Formation

The Fresno Formation consists of a sequence of ash falls, sandstones, conglomerate, ash-flow tuff, volcanic mud flows, breccias, some wind-blown material, and a number of lava flows. McKnight (1968, 1970) has mapped nine units in the Fresno Formation which are described in more detail in a companion volume on the Bofecillos Mountains (Deal 1976b). Some of the light-colored, poorly consolidated tuffaceous volcanic and sedimentary deposits are exposed for a short distance along the bed of Panther Creek north of Highway 170, and on the east side of Big Hill, northwest of the Teepees rest area in the eastern part of the study area. These beds are also exposed a short distance north of Highway 170 between the mouth of Rancherias Canyon and Tapado (Oso) Canyon. A prominent lava flow composed of latite porphyry occurs near the top of this unit and forms the prominent cliff immediately north of the highway for a few kilometers northwest of the mouth of Rancherias Canyon. Another lava flow of mafic trachyandesite is exposed near the top of the unit on the eastern end of Santana Mesa.

For more complete discussion of this unit, see McKnight (1968: 61-74) and Deal (1976b: Appendix 10).

Santana Tuff

During the time of the Bofecillos volcanic activity, the Santana Tuff was erupted from a vent somewhere to the southeast of the Bofecillos Volcano, probably in Mexico. It is a welded tuff (ignimbrite) like the Mitchell Mesa Tuff, and although it covers less area than does the Mitchell Mesa Tuff, the Santana is also highly useful in establishing the relative age of the volcanic units in the region. It is extremely important in the Colorado Canyon study area, because its type locality is at Santana Mesa in the eastern edge of the area, and the spectacular, massive, columnar-jointed cliffs of Santana Tuff dominate the landscape in the area. The western two-thirds of Colorado Mesa is capped by the Santana Tuff and in most of Colorado Canyon the Santana forms the walls down to river level. McKnight (1968: 74-77) describes this unit in detail. He states:

> It is ash-flow tuff composed of one to at least six (and probably more) partly-welded ash flows. West of Santana Mesa at the mouth of Panther Canyon it is about 550 feet thick. The Santana thins gradually to the northwest and pinches out across Tapado Canyon. It thins abruptly to the north and northeast, probably because of faulting before or during effusion; it pinches out over Fresno flows on the flanks of the Bofecillos volcanic cone, but extends almost to the head of Fresno Canyon as a layer mostly less than 5 feet thick.

Maxwell and Dietrich (1965) reported the northernmost-known outcrop of Santana at the northern end of Tascotal Mesa, about 30 km (18 miles) northeast of Colorado Canyon. McKnight (1968:74) reports an oral communication from Muehlberger who, during an air reconnaissance south of Colorado Canyon, observed that a tuff that looks like the Santana at Santana Mesa extends at least 16 km (10 miles) into Mexico.

As graphically illustrated in Colorado Canyon, the Santana weathers to form distinctive orange cliffs. Canyons cut into this unit are typically narrow gorges with near-vertical walls and uneven longitudinal profiles. The unevenness is caused by zones within the Santana that differ in resistance to erosion. This is particularly noticeable in the smaller tributaries to the Rio Grande such as Closed Canyon (Poquito Cañon or Lost Canyon) that cuts Santana Mesa.

The Santana is more than 30 m thick in most of the Colorado Canyon study area. Here it is commonly composed of one or more compound cooling units, each of which may have been formed by several eruptive events and each event spaced closely enough in time so that the underlying deposits were still quite hot. All of the eruptive material then welded into a single cooling unit. Each cooling unit consists of gradational layers of non-welded, moderately- or intensely-welded tuff. Appendix 3 reproduces McKnight's (1968) measured section 5 at the north end of Santana Mesa and along adjacent Panther Canyon where he inferred that six or more ash flows and two cooling units may occur. McKnight concludes:

> The source of the Santana Tuff is probably in Mexico south or southwest of Santana Mesa. The Santana thickens and the number of ash flows increases in that direction, probably because contemporaneous faulting or folding formed a topographic basin there. Perhaps the roof collapsed into its own magma chamber and the magma was displaced as pyroclastic material upward into the depression thus formed. The body of rhyolite porphyry at the southeastern end of Santana Mesa is similar in composition to the Santana; it may be an intrusion associated with the Santana vent area.

The intrusion referred to above by McKnight forms the massive, columnar-jointed cliffs and the physiographic barrier at the Big Hill. To the best of my knowledge, no one has made a detailed study of the similar intrusive mass that occurs at the mouth of Colorado Canyon on the Mexican side of the river (Fig. 5). The Big Hill intrusion is a faulted dome-shaped body of rhyolite porphyry at least 1800 m

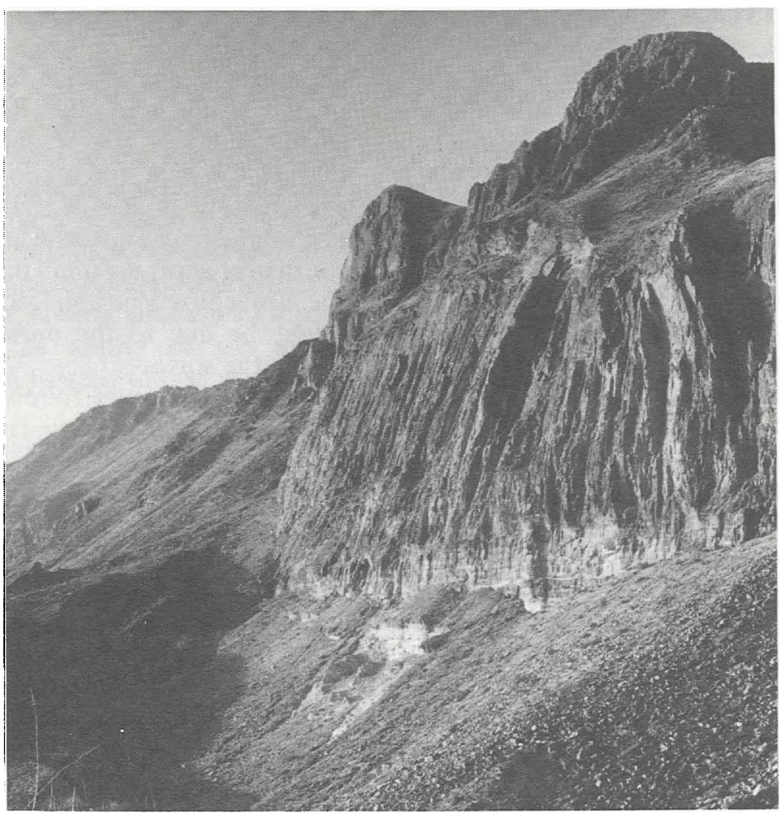

FIGURE 5

Massive, columnar-jointed cliffs of an intrusive mass on the Mexican side of the Rio Grande near the mouth of Colorado Canyon. (Photo by Reagan Bradshaw)

(6000 ft) across and about 250 m (800 ft) thick. It extends across the river into Mexico and the contact with the flanking Santana Tuff is poorly exposed or inaccessible. It appears to lie partially below and partially within the Santana Tuff. McKnight (1968: 108) discusses its composition and the nature of its contact in more detail.

Rawls Formation

About the same time that the Santana Tuff was spread over the area, the eruptions from the Bofecillos Volcano became more complex. More and more lava flows were erupted, not only from the central vent but also from other fissures in and around the Bofecillos eruptive center. Ash-fall and ash-flow tuff layers were spread over the Colorado Canyon area, probably both from Bofecillos vents and from other vents in Mexico and elsewhere.

Later flows from the Bofecillos vent were predominantly basaltic. Block faulting began before extrusion of the uppermost basalt flows, causing them to be interbedded with sedimentary accumulations in the down-dropped fault blocks. McKnight mapped the Rawls Formation in considerable detail, mapping 24 stratigraphic units (McKnight 1968; Deal 1976b: Appendix 10). Only a few of these units are exposed in the study area and they are restricted to the down-dropped fault blocks between Colorado Mesa and Santana Mesa. This area is generally a topographic low that extends from the western side of Big Hill northwesterly to Three Dike Hill at the north end of the study area.

A particularly scenic area of "balancing rocks" (also known as the "Anvil Rocks," "Davit Rocks," or "Hoodoos"), eroded from conglomeratic Member 9, occurs approximately 1 km southeast of the Tapado (Oso) Canyon bridge between State Highway 170 and the Rio Grande. At a few places Member 9 consists of breccia containing blocks as much as 2 m across. Such deposits probably represent talus and landslide debris along active fault scarps (McKnight 1968: 103). One such deposit is strikingly exposed in the graben about 1½ km (1 mile) north of the Redford Bolson in Las Burras Canyon.

Tertiary and Quaternary Faulting

A number of vertical faults with displacements of as much as 600 m (2000 ft) occur around the flanks of the Bofecillos Volcano and through the Colorado Canyon study area. These are referred to as normal faults and trend generally northwestward. Colorado Canyon occurs in the middle of a fault zone called the Redford-Lajitas Fault Zone by McKnight (1968: 121), which varies in width from 8 to 15 km (5-15 miles). The Redford-Lajitas Fault Zone is typical of fault zones found elsewhere in the Basin and Range province and is evidenced now by a jumble of relatively up-thrown blocks (horsts) and down-thrown blocks (grabens). The faults and major horst and graben blocks are shown in Figures 2 and 3.

Most of the course of the Rio Grande in West Texas is along the axis of a complex compound graben. The river usually follows the general position of the lowest fault block. The course of the Rio Grande through the Colorado Canyon study area is no exception. In the Redford-Lajitas Fault Zone, normal faults form a compound, step-faulted graben centered along the present course of the Rio Grande. Structural relief of the graben ranges from 300 to 760 m (1000 to 2500 ft) with individual displacements distributed more or less evenly over a broad belt of a dozen or more individual faults and tilted fault blocks, or may be concentrated on a single fault with 600 m (2000 ft) or more of throw. As can be seen in Figure 3, the southwest side of some faults on the United States side of the compound graben are up-thrown, producing horst blocks that interrupt the overall down-to-the-southwest step fault pattern (McKnight 1968: 125). The features are relatively more common along the northeast edge of the graben complex than near its axis. The intersecting, complexly arcuate faults are as much as 20 km (12 miles) long. Most are high-angle normal faults, but a few locally dip 45° or less. McKnight was unable to demonstrate any reverse faulting. At the western end of the study area, the Redford-Lajitas Fault Zone trends about N 50° W, but it is broadly accurate so that at the east end of the study area it trends approximately N 70° W. This change in angle is more pronounced at Tapado Canyon where the faults bend southwestward around the approximate outline of the Bofecillos Volcano. McKnight speculates that this might be due to the presence of igneous intrusions below the surface.

The major faults follow regional trends and were probably active during the period of Tertiary volcanism. Continued displacements along these faults have occurred since the cessation of volcanic activity. Displacements probably continued well into the Quaternary. In most places later movement along early-formed faults has obscured the evidence of earlier movement. In the Redford-Lajitas Fault Zone there is ample indirect evidence, in the form of abrupt thickening of stratigraphic sequences, to indicate early faulting (McKnight 1968:126). McKnight continues:

> About a mile northeast of Santana Mesa faulting occurred before implacement of the Santana, because its thickness across the fault ranges from 30 feet on the up-thrown side to more than 100 feet on the down-

thrown side; renewed movement on the fault separated the top of the Santana several hundred feet, and the abrupt change in thickness is only demonstrable in Madera and Panther Canyons.

Field relationships, however, indicate that most of the block faulting occurred after the deposition of volcanic strata: 1) faults cut the youngest volcanic strata and the bolson fill; 2) faults are not perceptibly more abundant in the older strata—fewer faults were mapped in the late- and post-volcanic bolson fill principally because exposures are poorer, rather than because of an actually decrease in fault abundance; 3) at no place in the area was a fault found truncated by strata older than Quaternary gravel; 4) significant differences in thicknesses of given intervals of volcanic strata across faults—indicating early faulting—are relatively uncommon. Dietrich (1965, p. 216) reported faults displacing Quaternary pediment gravel in the Presidio area, a fact suggesting that faulting continued throughout the later part of the Cenozoic era.

TERTIARY AND QUATERNARY SEDIMENTARY DEPOSITS AND EROSIONAL HISTORY

Introduction

Sedimentary fill in the basins along the Rio Grande accumulated during late Tertiary and Quaternary time. After an initial period of basin filling, the bolsons were breached and a through-flowing Rio Grande or Rio Conchos drainage was established through the Big Bend area. The Rio Grande experienced alternate times of rapid downcutting and relative stability, and the tributaries of the Rio Grande in the study area reflect those alternations. The alternations are caused by an interplay between two sets of processes: slope processes (all those processes that carry material downslope and provide sediments to the main streams) and the stream processes (those processes that determine the ability of the main streams to transport material toward the ocean and to cut their channels).

When the stream processes can carry away more material than is supplied from the neighboring hillsides by slope processes, the main streams excavate their channels, downcutting and lowering the floor of the main drainages. When slope processes dominate and provide more material than the stream processes can transport, the main drainages are filled with sedimentary material and valley filling occurs. When slope processes and main stream processes are in balance, conditions traditionally referred to as "stability" occur and, in arid and semi-arid regions, sloping surfaces of lateral planation (pediment surfaces) are developed on each side of the main stream. During times of more rapid downcutting the streams incise the previously-formed planation surfaces. The resultant stair-step-like sequence of gravel-mantled pediments and terraces is strikingly exhibited in much of the study area.

The Rio Grande valley through the study area consists of three sharply contrasting segments: 1) the segment to the northwest cut through the nonresistant valley fill of the Redford Bolson; 2) a middle segment where Colorado Canyon is cut through faulted resistant Tertiary volcanic strata and nonresistant bolson fill, and 3) a lower segment east of Big Hill in the Contrabando Lowland-Fresno Creek area where the river cuts prinicipally through nonresistant Upper Cretaceous sedimentary strata and poorly-consolidated volcanic ash and associated sedimentary deposits of the Chisos Formation.

Presidio Bolson and Bolson Fill

Immediately upstream from the Colorado Canyon study area are two bolsons (mountain-ringed desert basins) that are characteristic of most of the upstream two-thirds of the Rio Grande drainage system: the major Presidio Bolson and the smaller Redford Bolson. The Presidio Bolson is a major desert basin, and a study of it is highly significant to the understanding of the Quaternary history of the Rio Grande and Rio Conchos drainages. These two major rivers join in the Presidio Bolson. The much smaller Redford Bolson, although covering less areal extent, shares some of the history of the Presidio Bolson, occurs immediately upstream from Colorado Canyon, and is partially included in the study area.

Lampert (1953), Zinn (1953), Amsbury (1957, 1958), Dietrich (1954), Dickerson (1966), Haenggi (1966), McKnight (1968), Gries (1970), and Groat (1970a, 1970b, 1972) have made studies that include discussions of the Presidio and Redford Bolsons. Groat (1970a, 1970b, 1972) has synthesized all previous work in his dissertation, which concentrated on the Presidio and Redford Bolsons. Groat's publications are the primary references for an understanding of the sediments and groundwater in the bolsons. This area is shown in Figure 6 (Groat 1970a; 1972, Fig. 1).

There is much we do not know about the history of this segment of the Rio Grande. The Rio Grande-Rio Conchos system is the last major river in North America that does not have a fairly well-known developmental and erosional history, mostly because much of the critical evidence probably lies in Mexico and has not yet been examined. The interpretations I make in this report are the best guesses I can make from what is known today, colored by my prejudices about the Quaternary history of this area. All of these interpretations are open to modification or abandonment, and it is my hope that additional and better

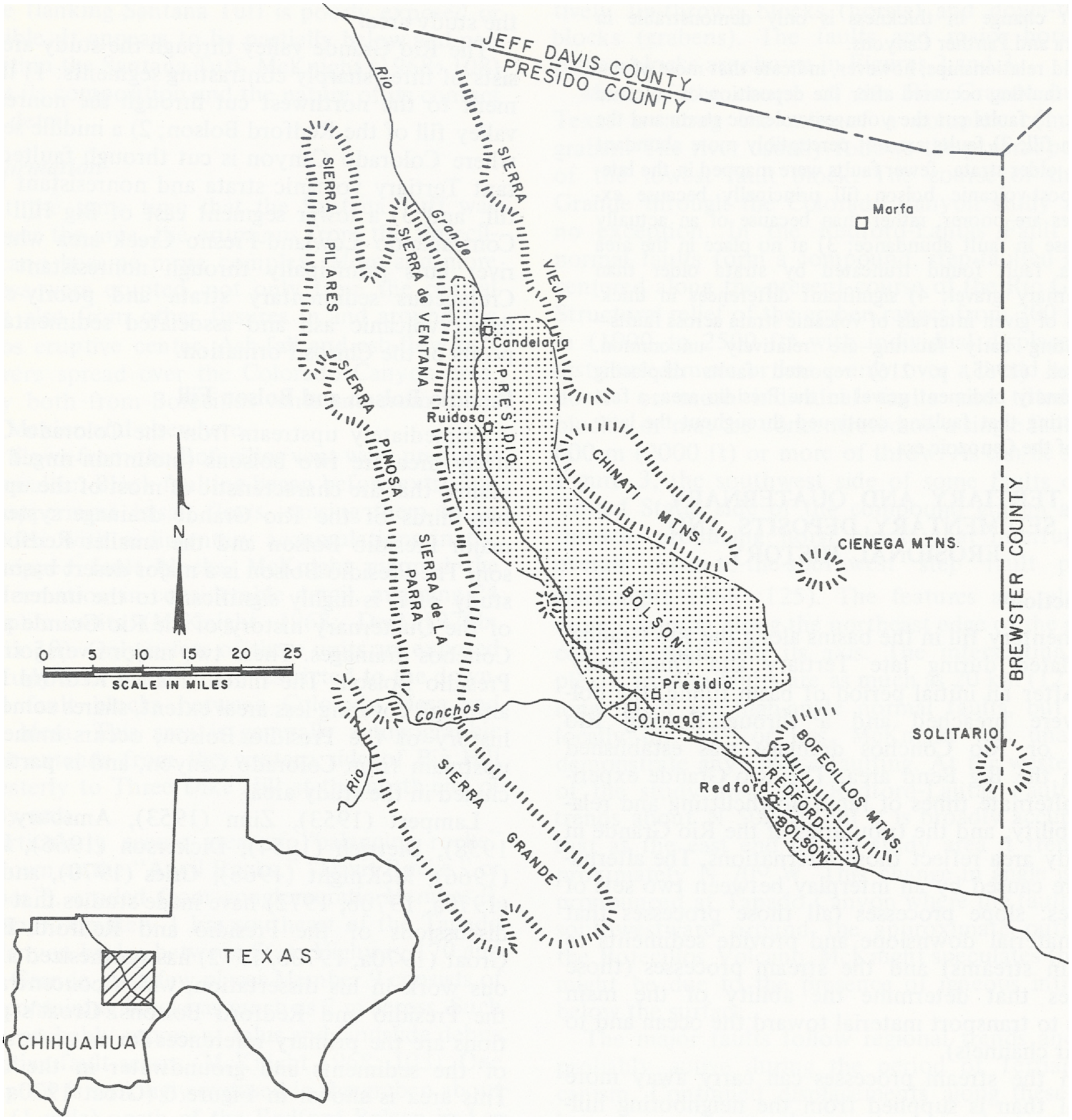

FIGURE 6

Map showing location of Presidio and Redford Bolsons and related features. (From Groat 1972: Fig. 1)

data will lead to an accurate understanding of the history of this river system.

Conceptually, the history of the bolsons can be subdivided into four sets of events: basin origin, filling by locally derived debris, influx of debris from more distant sources carried into the basins by the ancestral Rio Grande or Rio Conchos, and basin excavation by the downcutting Rio Grande system.

The structural basin containing the Presidio Bolson is part of the complex graben system that formed as a result of Basin-and-Range faulting which began in the Tertiary. Displacements along the bounding fault-zones gradually increased the relative elevation difference between the basin floor and surrounding mountains. Initially, the basin was much like many of the desert basins in the Chihuahuan and Sonoran deserts—a large, closed depression with no outlet to the sea and receiving sediments only from the surrounding mountains. As displacements along the bounding fault-zones continued, relief gradually continued to increase. Flashflood runoff and slope processes eroded the surrounding highlands, continuing to fill the basin with locally-derived debris. Sediments deposited during this phase are typically coarsest near the mountains, becoming progressively finer toward the center of the basin, where silt and clay were deposited in intermittent lakes. During most seasons, the center of the basin was a typical desert playa (dry lake bed).

Some cross sections characterizing the sediments filling the Presidio Bolson are shown by Groat (1972: Fig. 2), reproduced here as Figure 7. Groat (1972:7) describes the bolson sediments as follows:

> Previous workers in the Presidio Bolson have recognized the gradation of rock types in the bolson fill from conglomerate near the mountains to mudstone near the basin center. Zinn (1953:26) observed the lateral gradation of sediment types and applied the term "facies" to different lithologic units in the southern part of the Presidio Bolson. Amsbury (1957:102) and Dietrich (1965:152) recognized the variations but did not map them. Haenggi (1966:125), working in Mexico near the northern end of the bolson, mapped a gravel-conglomerate facies and a sandstone-siltstone-claystone facies that grade into each other laterally and vertically. Dickerson (1966:18, 19), working in the Hot Springs area, described three facies—clay, sandstone, and conglomerate—separated by transition zones where the facies interfinger. McKnight (1968:111) described the bolson fill in the Redford Bolson but did not map the separate facies.
>
> Although the pattern of conglomerate nearest the mountains grading through sandstone into claystone near the basin center is persistent, the zones in which these rock types interfinger are commonly broad, and with the exception of the claystone or mudstone, no rock type is exclusively present in any large area. Thus, it is not possible simply to designate facies, such as "sandstone facies" or "conglomerate facies," and map areas containing only sandstone or conglomerate because these rock types are not exclusively present over significant areas.
>
> Facies boundaries are drawn on the basis of features observable at the outcrop. The boundaries are valid only for the exposed part of the bolson fill because available subsurface information is far too sparse to permit interpolation; thus, the boundaries and interpretations based on facies distributions are subject to the limitations posed by outcrop distribution.

Figure 7 illustrates common stratigraphic relationships in the bolson and the application of the terminology used by Groat. He continues:

> The facies and lithosomes are defined on the basis of quantitative and semiquantitative field studies of nearly all available areas of outcrop. Each outcrop visited was described and either the section was measured or an estimation was made of the percent of each rock type present. Five textural groups were defined that reflect the most common and widespread lithologic associations. The five textural groups or lithosomes were combined into two facies, each of which was given an informal name reflecting the position in the basin where it crops out most extensively: basin-margin facies and basin-center facies.

Groat's detailed descriptions of these facies are included in Appendix 4.

At some time in the history of the basin filling, it is probable that the ancestral Rio Grande (fed by snowmelt in southern Colorado and northern New Mexico) or the ancestral Rio Conchos (fed by rainfall in the Sierra Madre Occidental southwest of Chihuahua City) spilled over the divides and into the Presidio Bolson from either the northwest or southwest. At this time the character of the sedimentation within the Presidio and Redford Bolsons changed dramatically; a permanent lake was probably formed in the center of the basin, and river-fed sediments accumulated that contained rock fragments derived from sources far outside the local area.

A good understanding of the late basin-filling phase (during the time the Presidio Bolson was accumulating the river-fed sediments from upstream areas) is necessary to correctly understand the history of the basin. Unfortunately, later erosion seems to have excavated and removed most or all of the center-basin deposits that record those events. Gravels at the north end of the Presidio Bolson, clearly derived from outside of the basin and associated with a volcanic ash deposit, have been described by Groat (1972:31-32) and Hawley (1975: 145-146). These sediments, however, were clearly deposited during the valley-excavation phase (Hawley 1975), and not the earliest basin-filling phase under discussion here. Additional field

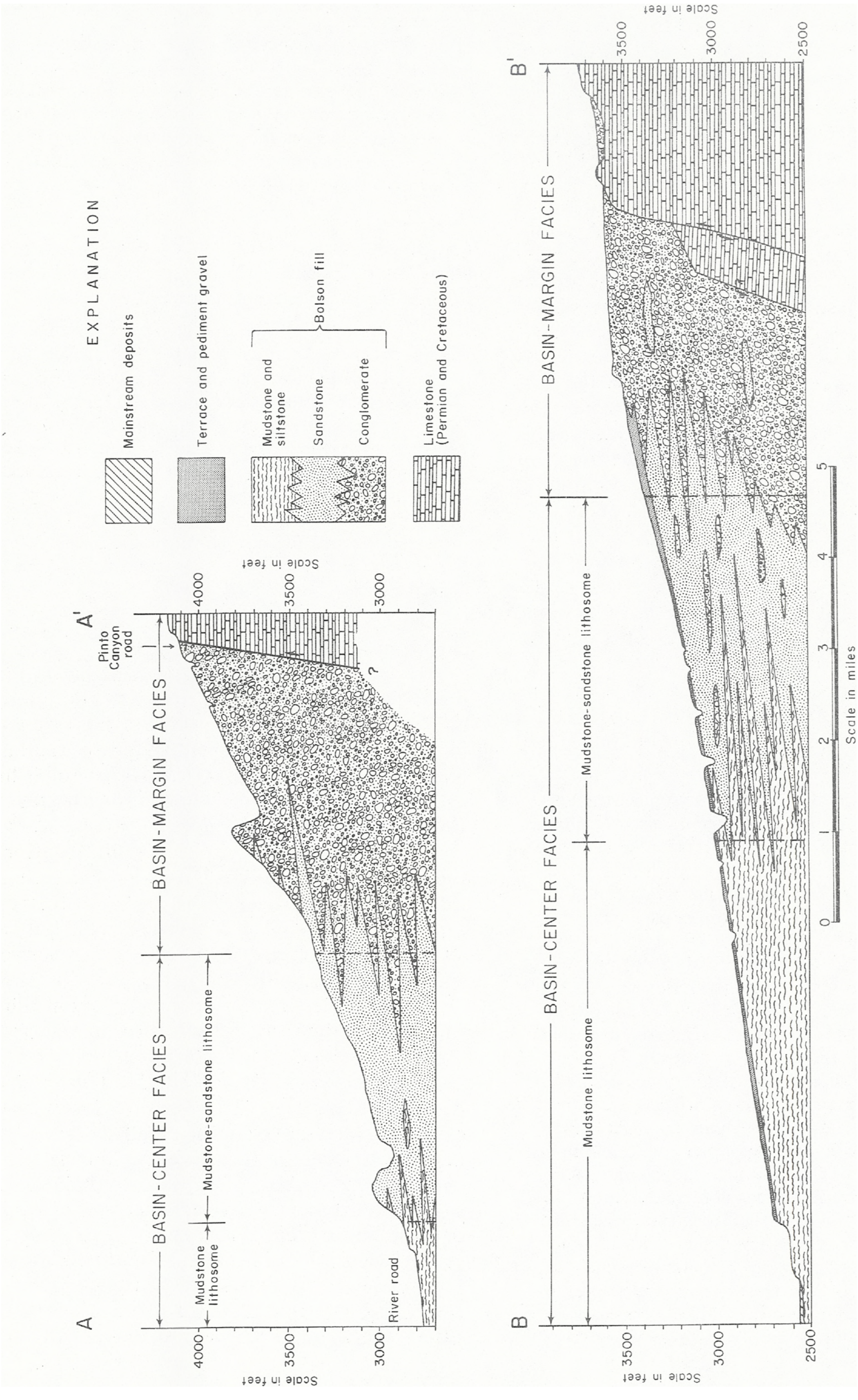

FIGURE 7
Cross sections through the Presidio Bolson. Faults not shown.
(From Groat 1972: Fig. 2)

work, probably in Mexico, will be necessary before these events can be better understood.

During the basin-filling phase essentially all material brought into the basin by the Rio Conchos or the Rio Grande, or derived locally from the slopes surrounding the basin, accumulated and stayed within the Presidio and Redford Bolsons. As soon as the ancestral Rio Conchos or ancestral Rio Grande began supplying sediments to the basin, the rate of sedimentation and basin-filling increased markedly. Eventually the basin floor was raised and the lake within it continued to grow until the lake level was high enough to spill southeastward across the present location of Colorado Canyon into a lower basin downstream. When this occurred, the basin-filling phase of bolson history ended and the excavation phase began.

I should note here that some geologists argue that headward-erosion by an ancestral lower Rio Grande caused the downstream portion of the river to work its way into the Presidio area from the southeast and may have caused integration of the drainage. Although this process must have been a factor somewhere along the length of the Rio Grande drainage, my current feeling is that it did not play an important role in the development of the drainage through the study area.

I therefore feel that the initial course of the Rio Grande was established across the floors of sandy, silty, and gravelly basins. Meandering stream patterns develop when a river is cutting through and shifting the unconsolidated sediments that comprise its own floodplain, and I assume that most of the meandering patterns now perserved in the Rio Grande Canyons developed at that time. Initial incision by the river began by removing some of the unconsolidated basin-filling deposits, but soon the river started to cut into older and harder rocks that underlay the basin floors. As the main channel began to saw into the resistant, underlying rocks, canyons began to be formed and the meandering pattern of the river was trapped and preserved as meandering canyons. Those meanders are considered as superimposed and inherited from an older river bed that had occurred at an elevation well above (probably several hundred meters) the present river level.

With increased downcutting along the Rio Grande and the incision of Colorado Canyon, the tributary drainages also began to cut canyons: Fresno Canyon, Panther Canyon (Cañon Leon), Closed Canyon, Rancherias Canyon, Tapado Canyon (Oso Cañon), Las Burras Cañon, and the other canyons draining the Solitario, the Bofecillos Mountains, and the mountain ranges to the south in Mexico.

The sediments excavated from the bolsons were transported downstream and probably were deposited temporarily as late basin-filling sediments in a downstream basin. Ultimately most of the debris was probably carried into the Gulf of Mexico and deposited as finer-grained marine sediments.

Groat (1972:29) describes the events that then occurred in the Presidio and Redford Bolsons:

> As excavation proceeded, the sidestreams and mainstream left generally thin veneers of sediments over terrace and pediment erosional surfaces, parts of which were subsequently abandoned and stand as remnants above modern streams. These terrace and pediment gravels crop out over the greatest surface area of the bolson. At various times and places the erosional process was interrupted by local, perhaps even basin-wide, accumulations of sidestream alluvium deposited on the mainstream valley floor as alluvial fans and in sidestream valleys as valley fill.

The complex of excavation-phase deposits is described in more detail by Groat (1972:26-32) and is reproduced here as Appendix 5.

Redford Bolson

The Redford Bolson has a similar history and is described by Groat (1972:32-33) as follows:

> The Redford Bolson is a narrow, complex graben bordered on both the east and west sides by volcanic highlands; it is the southeastward extension of the larger Presidio structural basin. The Redford Bolson is much smaller than the Presidio Bolson; it is only 6 miles wide at its broadest point and is 12 miles long. The depositional history of the Redford Bolson is similar to that of the Presidio Bolson and the sedimentary fills of the two are continuous.
>
> Most of the Redford Bolson fill is interbedded, poorly sorted pebbly sandstone and sandy conglomerate; stratification is irregular and poorly defined. These deposits lap onto the adjacent fault-block complex from which they were derived. Sandstone and siltstone interfinger with the conglomerate near the basin center; they contain caliche nodules and the fine network of calcium carbonate "tubes" described in the section on calcium carbonate. Sandstone and mudstone occur adjacent to the bordering highland on the east, between the major gravel bodies which are located near the canyon mouths of modern streams. The shift of the locus of fine-grained sediment deposition toward the eastern mountain edge could have resulted from an increased supply of detritus from the west occasioned by faulting and uplift there. This is a relatively common phenomenon in bolsons in the Basin and Range Province.
>
> Mudstone, claystone, and siltstone similar to sediments in the mudstone lithosome of the Presidio Bolson occupy a small area near the center of the basin. These mudrocks interfinger with sandstone and conglomeratic sandstone characteristic of most of the deposits. The fines are poorly and discontinuously exposed, hence details of their geometry are unknown. In one place, however, along the large unnamed creek between Buzzard

(Auras) and Burrow (Las Burras) Creeks, the lateral migration of mudrocks toward the north, over gravelly deposits, is seen in more or less continuous exposures.

The fine-grained bolson sediments of the two basins are separated by pebbly sandstone and conglomerate, indicating that an alluvial divide created a sub-basin in the Redford graben in which a separate playa existed. McKnight (1968, p. 113) believed that the muds in the Redford Bolson were derived from upstream, from the Presidio Bolson, but the presence of a wedge of coarser-grained deposits between the two areas does not support this interpretation.

Excavation-phase deposits are similar in kind and mode of occurrence to those in the Presidio Bolson. Sidestream-terrace deposits mantle distinct terrace remnants standing above and adjacent to the larger sidestreams, those that head in the bordering volcanic terrane. Older mainstream deposits underlie sidestream-terrace gravels near the axis of the basin and are restricted to a narrow belt in the axial area.

Exposures of bolson fill in the Mexican part of the Redford Bolson are limited to the few bluffs near the Rio Grande. Nearly the entire extent of the bolson, from the edge of the bordering highland to the Rio Grande, is a broad, washed plain of low, irregular terraces and sidestream fans. Large sidestreams are not common, hence gravel-capped pediment and terrace remnants are not common. Topographic maps are not available, but this erosional-depositional plain of low relief has a steep gradient, probably 200 feet per mile or greater. Faults are present in the fill along the river and in the volcanic rocks near the southern end of the basin in Mexico; the steep gradient may be directly related to a series of fault blocks that step sharply down toward the river.

Age of the Rio Grande-Rio Conchos System

Some major revisions, both in our understanding of the Quaternary history of the western United States and in the methodology that allows an understanding of that history, have occurred in the last decade. Traditionally, the Quaternary history of the United States has been linked to the concept of four major continental glaciations, separated by major interglacial times. This chronology is based in part on hypotheses that are now known either to be incorrect or to contain serious flaws (Deal 1971). It now appears that there probably were many more glaciations (possibly as many as 40 or more) and much greater complexity of glacial, interglacial, and pluvial times during the Quaternary Period than have been classically defined.

Workers in the southwestern United States, by circumstance, have been forced to attempt to correlate Quaternary events in the southwest with the classical glacial sequence developed in the mid-continent area. This, coupled with the awareness that serious flaws may exist in the classical sequence, has resulted in the development of much more precise, nonglacial methods of producing geologic chronologies in the Southwest. These developments include the fields of tephrochronology (volcanic-ash chronology), radiometric dating, magnetic polarity stratigraphy, vertebrate paleontology, soil-geomorphology, and detailed field investigations. Probably the most impact has been from significant advances in tephrochronology and magnetic polarity stratigraphy.

In 1965, for example, the concept of a single, widely distributed, Pearlette ash, assumed to be of late Kansan age and originating as a very widespread ash deposit that erupted during one extremely explosive event from the vicinity of what is now Yellowstone National Park, was almost universally accepted (Hibbard and others 1965). The Pearlette ash is now known to be composed of three ash-fall units from Yellowstone sources, respectively referred to as types B, S, and O Pearlette that erupted two million years, 1.2 million years, and 0.6 million years before the present (Izett and others 1972).

Recent studies of rhyolitic eruptive centers at Yellowstone National Park, Long Valley, California (Bishop Tuff), and the Jemez Mountains, New Mexico (Bandelier Tuff) and dating of ash falls erupted from these centers at many well-established vertebrate fauna localities also demonstrate that revisions in the Quaternary chronology and stratigraphic correlations of these ash deposits are in order (Hawley 1975; Christiansen and Blank 1972; Izett and others 1970, 1972; Naeser and others 1973; Doell and others 1968; Smith and Bailey 1968). Revisions in stratigraphic concepts are further supported by magnetic polarity stratigraphy and dated volcanic events in New Mexico (Doell and others 1968), and ash-bearing vertebrate localities in southeastern Arizona (Johnson and others 1975), New Mexico (Reynolds and Larsen 1972), and in West Texas (Izett and others 1972). Hawley (1975) has summarized all of this information and presents a series of "state of the area" discussions, charts, and tables in an effort to stimulate further thought on the Quaternary stratigraphy and geomorphic processes in the southwest and, in particular, in the Rio Grande drainage area.

In his summary, Hawley concludes that the bulk of the upper Santa Fe deposits in south central New Mexico can be traced nearly continuously along the Rio Grande valley from Socorro to some point south of Las Cruces, New Mexico. In his Figure 2, Hawley (1975) shows an early-to-middle Quaternary major drainage trend along the present course of the Rio Grande from El Paso through Candelaria, and into the Presidio Bolson. Interbedded with the ancestral Rio Grande deposits are Pearlette-type ash beds in the vicinity of both Fort Hancock and Candelaria, Texas. Hawley (verbal communication, November 1975) stated that fission-track analysis of the ash deposit near Fort Hancock has established it as a type B Pearlette ash with a correlated age of two million years before the present. If the ash present in the Rio Grande Terrace sediments exposed along Sandiguela Creek near Candelaria is also a Pearlette type B deposit, then an ancestral Rio Grande must have existed in West Texas more than two million years ago. (See also discussion of the Sandiguela Creek exposures in Groat 1972: 31; reproduced in Appendix 5).

Earlier evidence indicated that the Rio Grande, heading in northern New Mexico, terminated in Lake Cabeza de Baca in middle Pleistocene time and resulted in widespread basin-filling in the Las Cruces area as recently as 200,000 years ago (Strain 1966, 1970; Hawley 1975). The widespread basin-fills that resulted from this ponding of the Rio Grande are referred to as the Camp Rice Formation, deposition of which terminated in late middle Pleistocene time when the Rio Grande apparently overflowed through the mountain gap at El Paso. This evidence encouraged the thought that the Rio Grande may not have existed between El Paso and Presidio until late middle Pleistocene time. The volcanic ash chronology would indicate otherwise, suggesting that an early river system may have existed as much as two million years ago and that subsequent uplift and tilting of the Organ-Franklin chain of fault-glock mountains diverted the river westward, away from its El Paso-Presidio course and into Lake Cabeza de Baca to the west and south prior to the Camp Rice Formation (Hawley 1975:146).

It is interesting to note that Belcher (1975b), although acknowledging that the present Rio Grande is a geologically youthful feature, pleads a case for the great antiquity of the ancestrial Rio Grande-Rio Conchos-Pecos drainage system. In doing so, he resurrects reasoning popular with the early geological explorers of the western United States, justified in the first regional study of the Rio Grande in Colorado and New Mexico by Bryan (1938), and discarded by most contemporary field workers. Belcher's arguments are unfortunately based largely on the interpretations and conclusions of others (many of which were in turn based on much too simplified models of Quaternary history) and negative evidence (such as no high gravels present at some of the few places Belcher field-checked), and are supported by little actual field work.

Where Belcher describes areas of the Rio Grande drainage that I know well, I find I disagree strongly with his conclusions. Many of his observations in the Big Bend country can easily be interpreted in ways that do not support his belief in the very great age of the Rio Grande. It is a great disappointment to see that he did not adequately discuss some of the more telling alternative explanations.

A basic flaw Belcher inherited from previous workers is a neglect of the importance of the little-known history of the Rio Conchos. As mentioned later in this report, Tables 1, 2, and 3 illustrate the disproportionate contributions of the Rio Conchos and Upper Rio Grande to the discharge of the lower Rio Grande below Presidio. Nineteen years of record (1896 through 1914) of the uncontrolled flow of the river system prior to major impoundments upstream show that over 70% of the water in the Rio Grande downstream from Presidio was supplied by the Rio Conchos. Not only did the Upper Rio Grande (flowing from El Paso) contribute less than 30% of the water that was in the river below its confluence with the Conchos, but during those same 19 years of daily record, there were 41 months when the river bed was essentially dry. During 30 of those months (including one 6-month and one 7-month period), no flow at all was recorded in the Upper Rio Grande just upstream from the confluence.

Much of Belcher's reasoning is based on his laudable efforts to treat the river system as a unit. But, as far as the Big Bend is concerned, he neglects to provide data necessary to reasonably discuss 70% of this unit and has ended up with a discussion that is largely a mental excerise of logical arguments, unfortunately built on a base of questionable interpretations.

As indicated earlier, much is still unknown about the detailed developmental history of the Rio Grande-Rio Conchos-Pecos River drainage through the heart of the Chihuahuan Desert. Chances are good that the Pecos River, Devils River, and drainages from Mexico downstream from Del Rio represent the oldest through-flowing rivers in the basin. Next, the Rio Conchos, probably by basin overflow, joined a tributary to the ancestral Pecos River. The last major integration was probably the overflow of the Upper Rio Grande into the Rio Conchos drainage in the vicinity of Presidio. Whether the river system is relatively young or relatively old, there is no question that it has played a significant role in the development of both the physical landscape and the biological communities, as well as the exploitation of the area by man. Unravelling the puzzle and accurately dating these events is the most fascinating major problem left in our attempts to understand the erosional history of western North America. The knowledge gained by our brief studies along the river can only add to our long-term efforts to understand the area.

MINERAL RESOURCES

The most important mineral resource in the Colorado Canyon study area is water, and the most important water is that flowing in the Rio Grande itself. Historically, water has flowed both from the north (northern New Mexico and southern Colorado) and from the south (southwest of Chihuahua City). Prior to the advent of damming on the Rio Conchos and Rio Grande in 1915, a copious flow of cold water was normally provided from the Rio Grande drainage by snowmelt each spring. Table 1 shows the historic flow figures for the Rio Grande and Rio Conchos at Presidio. Impoundments along the Rio Grande have almost totally terminated the flow in the Rio Grande above Presidio. As recounted in an earlier report on the Capote Falls Area, Presidio County (Deal 1973), accounts translated from early Spanish explorers indicate that the streambed of the Rio Grande between Presidio and El Paso was occasionally dry prior to any upstream impoundments (Tables 2 and 3). Extensive upstream use of the waters of the Rio Grande (note the effect of Elephant Butte Reservoir in 1915 in Table 1) is unquestionably quite significant in reducing flow today, but it seems that this artificial impoundment has only accentuated the problems of low streamflow in an already arid area, causing the recurrent droughts and dry stream beds of the past to become nearly permanent along some reaches of the river.

Impoundments by the Mexican government on the Rio Conchos in recent years have further accentuated the problem. Most of the water that flows through the Colorado Canyon study area today comes from the Rio Conchos (97% for the 10 years from 1964 through 1973; Table 1). As a result, streamflow along this reach of the Rio Grande is almost totally dependent upon how much water is released from the impoundments in both the United States and Mexico. Current river conditions can be ascertained by contacting the International Boundary and Water Commission in El Paso, Texas. Table 4 lists the height and discharge records for the last 10 years of the Rio Grande at the gaging station just downstream from the mouth of Alamito Creek, about 32 km upstream from Colorado Canyon.

Few other mineral resources appear to be important in the Colorado Canyon area. For a brief description of the mineral resources of the surrounding countryside, reference should be made to the discussions in the companion volumes on the Solitario, the Bofecillos Mountains, and Fresno Canyon (Deal 1976a, 1976b, 1976c).

ACKNOWLEDGEMENTS

The preservation of the natural state of the study area around Colorado Canyon is a result of the wise management practices of Big Bend Ranch and the Diamond A Cattle Company, who not only allowed but encouraged our study of the area. The assistance of all those involved with the ranch, R. R. Anderson, R. B. Anderson, Joe Mims, Mark Davis, numerous ranch hands, and especially Ralph Hager, the ranch foreman, was greatly appreciated. Ralph was particularly generous with his help. He not only provided a great deal of information about the area but supplied occasional equipment and assistance at times of vehicle malfunction and was a source of good fellowship as well. Ralph additionally spent several days with the field team, assisting with the data gathering and the acquisition of field collections. I think that all of the members of the Natural Area Survey field party learned to share the love and appreciation of this area held by the owners and workers on the Big Bend Ranch. We are grateful to have had the opportunity.

I additionally want to thank the staff and students from the Biology Department at Sul Ross State University that assisted in the program, especially Dr. A. Michael Powell. Jack Burns and Bob Walters, science teachers at the Alpine High School, also provided significant field assistance. Rick Sohl and Bill Sohl, of Alpine, helped by making available a 4-wheel drive vehicle and radio communications that proved invaluable when the field team had two immobile field vehicles. Jack Burns also made available his 4-wheel drive truck, which turned out to be the major workhorse for our crew. Our study was a major group effort and many helped make it a success. We thank all of you.

TABLE 1

FLOW OF THE RIO GRANDE AND RIO CONCHOS NEAR PRESIDIO, TEXAS

RGU: Upper Rio Grande Station, 7.8 miles upstream from the confluence with the Rio Conchos
CON: Rio Conchos Station, 1.5 miles upstream from the confluence with the Rio Grande
RGL: Lower Rio Grande Station, downstream from the confluence with the Rio Conchos and 1.7 miles upstream from the international bridge at Presidio.

Discharge in Acre-Feet. Data from International Boundary and Water Commission

Year	Station	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total
1896	RGU**	6,990	2,690	0	473	22,100	28,900	43,400	19,600	18,600	39,000	4,020	1,410	187,183
	CON**	48,300	42,900	33,800	24,000	31,600	55,100	114,100	231,200	400,200	167,800	66,400	58,600	1,279,000
	RGL**	53,900	49,100	43,200	37,700	77,500	111,700	148,500	239,700	384,700	178,100	74,500	67,400	1,466,000
1897	RGU**	12,200	4,000	0	53,600	206,000	304,000	103,000	66,200	52,800	83,200	26,400	33,500	944,900
	CON**	86,800	76,900	60,600	43,200	56,700	99,000	213,800	415,000	718,400	301,200	119,200	105,200	2,296,000
	RGL**	119,300	108,500	95,600	83,300	171,400	246,900	328,300	529,900	850,400	393,700	164,600	149,100	3,241,000
1898	RGU**	24,400	20,400	11,400	56,400	95,300	60,800	110,000	38,500	13,600	0	0	2,950	433,750
	CON**	44,900	39,800	31,400	22,300	29,300	51,200	110,600	214,800	371,700	155,900	61,700	54,400	1,188,000
	RGL**	59,700	54,300	47,800	41,700	85,800	123,600	164,300	265,200	425,600	197,000	82,400	74,600	1,622,000
1899	RGU**	6,180	4,260	1,060	2,830	3,380	3,420	37,500	16,800	10,000	1,750	1,470	216	88,866
	CON**	27,000	24,000	18,900	13,400	17,700	30,900	66,700	129,500	224,000	93,900	37,200	32,800	716,000
	RGL**	29,600	27,000	23,800	20,700	42,600	61,300	81,500	131,600	211,200	97,800	40,900	37,000	805,000
1900	RGU	3,870	1,950	711	0	3,930	46,800	9,830	2,500	12,100	11,100	0	0	92,791
	CON	27,700**	34,700**	22,300**	8,110**	12,900	15,400	270,000	378,000	160,000	94,200	24,400	14,600	1,062,310
	RGL	31,600**	36,600**	23,000**	8,110**	16,800	62,900	281,000	381,000	173,000	106,000	24,400	14,600	1,159,010
1901	RGU	0	0	0	0	43,100	41,600	8,450	28,400	26,900	11,400	9,320	4,980	174,150
	CON	11,100	17,400	12,200	2,420	1,200	3,100	52,200	80,900	103,000	63,100	26,000	13,500	386,120
	RGL	11,100	17,400	12,200	2,420	44,300	45,400	61,400	110,000	131,000	75,200	35,300	18,500	564,220
1902	RGU	4,740	1,610	0	0	0	159	34,900	6,290	12,200	198	1,680	496	62,273
	CON	11,200	6,230	3,610	1,450	674	2,010	328,000	344,000	627,000	79,300	33,400	29,800	1,466,674
	RGL	15,900	7,840	3,610	1,450	674	2,870	364,000	351,000	640,000	80,200	35,100	30,300	1,532,944
1903	RGU	0	0	3,040	16,600	74,800	103,000	167,000	16,100	4,720	317	0	0	385,577
	CON	22,000	64,000	27,100	7,500	5,500	47,300	25,300	95,200	144,000	119,000	23,200	15,500	595,600
	RGL	22,000	64,000	30,100	24,100	80,300	151,000	193,000	112,000	149,000	120,000	23,200	15,500	984,200
1904	RGU	0	0	0	0	0	11,800	100	40	17,400	209,000	51,800	29,000	319,140
	CON	11,000	6,810	4,670	1,520	5,230	38,300	37,400	56,400	1,460,000	399,000	105,000	98,000	2,223,330
	RGL	11,000	6,810	4,670	1,520	5,230	50,800	38,200	57,100	1,480,000	604,000	157,000	127,000	2,548,330
1905	RGU	23,600	23,400	136,000	115,000	262,000	604,000	143,000	32,200	22,800	4,630	9,510	36,600	1,412,740
	CON	44,600	43,200	44,000	28,200	21,000	53,400	142,000	407,000	446,000	285,000	251,000	261,000	2,076,500
	RGL	68,200	66,600	180,000	143,000	283,000	658,000	336,000	440,000	469,000	290,000	261,000	298,000	3,492,800
1906	RGU	22,800	28,700	21,800	40,000	228,000	231,000	72,500	61,100	12,500	15,500	40,800	62,600	837,300
	CON	89,200	187,000	79,200	24,700	13,100	23,400	557,000	1,080,000	433,000	112,000	46,100	43,400	2,688,100
	RGL	112,000	216,000	101,000	64,600	241,000	255,000	630,000	1,140,000	446,000	128,000	86,900	106,000	3,526,500

**Estimated

TABLE 1 cont.

		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total
	RGU	51,300	42,800	36,000	113,000	162,000	320,000	272,000	104,000	173,000	60,600	57,800	35,100	1,427,600
1907	CON	38,200	22,000	11,600	3,200	10,100	24,400	63,500	135,000	353,000	81,700	257,000	246,000	1,245,700
	RGL	89,500	64,800	47,600	116,000	172,000	345,000	336,000	240,000	527,000	143,000	315,000	281,000	2,676,900
	RGU	30,500	26,100	29,900	49,900	84,400	33,200	11,500	41,500	25,400	0	0	2,560	334,960
1908	CON	39,900	23,100	10,100	1,300	4,000	7,300	73,200	346,000	388,000	32,900	24,800	29,800	980,400
	RGL	70,400	49,200	40,000	51,000	88,300	41,100	85,200	389,000	414,000	33,600	24,800	32,400	1,319,000
	RGU	8,250	5,250	4,340	11,000	147,000	153,000	49,500	4,360	81,800	14,000	6,660	10,000	495,160
1909	CON	30,800	25,800	12,500	10,000	20,100	28,400	311,000	401,000	366,000	57,500	27,200	60,000	1,350,300
	RGL	39,100	31,000	16,800	20,800	167,000	182,000	361,000	406,000	449,000	72,200	33,900	70,000	1,848,800
	RGU	18,700	12,400	33,800	67,100	223,000	21,900	2,340	0	248	0	0	0	379,488
1910	CON	72,700	34,200	17,100	18,300	1,100	46,500	129,000	43,400	125,000	31,300	14,800	5,140	538,540
	RGL	91,400	46,600	50,900	85,200	224,000	69,000	132,000	44,000	126,000	32,000	14,800	5,140	921,040
	RGU	0	982	1,330	1,550	139,000	157,000	292,000	89,200	9,040	138,000	81,800	52,600	962,502
1911	CON	2,230	9,620	6,450	10,600	53,100	220,000	230,000	151,000	250,000	164,000	106,000	60,400	1,263,400
	RGL	2,230	10,600	7,780	12,000	143,000	378,000	522,000	241,000	260,000	303,000	188,000	113,000	2,230,610
	RGU	51,300	26,700	24,700	68,300	159,000	427,000	121,000	61,000	43,300	8,380	3,850	23,400	1,017,930
1912	CON	37,400	27,600	18,700	5,100	8,100	6,400	14,600	305,000	594,000	173,000	42,000	31,900	1,263,800
	RGL	88,700	54,300	43,400	73,200	167,000	434,000	136,000	367,000	638,000	182,000	45,900	55,300	2,284,800
	RGU	7,930	19,800	11,300	6,810	48,500	24 300	5,540	883	5,770	1,530	535	8,150	141,048
1913	CON	18,300	68,100	95,700	10,900	13,000	37,000	26,000	67,100	143,000	20,900	4,040	4,750	508,790
	RGL	26,200	87,900	107,000	17,500	61,400	61,900	31,900	68,600	149,000	123,100	4,570	12,900	651,970
	RGU	5,440	2,140	12,000	38,300**	160,000**	195,000**	137,000**	82,600**	22,600**	56,000**	38,300**	64,700**	814,080*
1914	CON †	8,160	7,120	6,500	4,050**	117,000**	444,000**	426,000**	488,000**	532,000**	396,000**	153,000**	111,000**	2,692,830*
	RGL	13,600	9,260	18,500	42,200**	277,000**	639,000**	562,000**	570,000**	555,000**	452,000**	191,000**	176,000**	3,505,360*
	RGU**@	27,400	20,600	18,000	12,200	48,700	57,900	58,400	62,200	61,700	25,000	1,980	5,160	399,240
1915	CON**	17,000	76,300	54,100	4,050	80,700	85,000	61,700	27,800	218,000	146,000	67,800	65,300	1,003,750
	RGL**	44,000	96,900	72,100	15,800	129,000	143,000	119,000	89,600	280,000	171,000	69,800	70,500	1,400,700
	RGU**	6,280	7,010	9,120	14,400	23,200	34,800	10,000	40,200	16,700	32,200	3,470	30,800	228,180
1916	CON**	4,050	8,760	4,050	4,050	4,050	4,050	22,900	105,000	221,000	107,000	29,800	8,510	523,220
	RGL**	10,300	15,800	13,200	17,900	27,000	38,600	32,200	145,000	238,000	139,000	33,300	39,300	749,600
	RGU**	29,100	30,200	22,200	12,200	17,400	16,200	64,800	77,700	59,900	45,200	29,100	34,700	438,700
1917	CON**	22,000	8,840	4,050	4,050	4,050	4,050	4,050	18,400	1,240,000	266,000	18,200	4,050	1,537,740
	RGL**	51,100	34,000	26,200	15,600	21,100	19,900	67,900	95,500	1,300,000	251,000	47,300	38,800	1,973,400
	RGU**	10,200	14,500	16,900	8,700	14,100	7,350	12,500	40,300	6,400	23,800	25,200	11,300	191,250
1918	CON**	4,050	4,050	4,050	4,050	4,050	22,600	4,050	264,000	97,300	122,000	30,700	33,400	594,300
	RGL**	14,200	18,600	21,000	11,900	17,600	29,500	15,300	303,000	104,000	146,000	55,900	44,700	781,700
	RGU	8,440**	9,500**	19,300**	16,600**	31,900**	27,100**	46,200**	36,300**	66,100*	30,300	10,700	2,400	304,240*
1919	CON**	83,300	6,810	4,050	4,050	4,050	4,050	223,000	759,000	717,000	284,000	45,300	23,400	2,158,010
	RGL**	91,700	16,300	23,400	19,200	35,400	30,700	268,000	795,000	783,000	314,000	56,000	25,800	2,458,500
	RGU	7,440	1,780	5,290	11,000**	18,500**	37,600**	25,500**	78,700**	45,000**	55,000**	23,400**	19,800**	329,610*
1920	CON**	45,700	17,700	4,050	4,050	28,900	61,500	49,100	936,000	1,093,000	82,000	38,100	13,100	2,373,200
	RGL**	53,100	19,500	9,340	14,200	46,900	98,600	73,300	1,014,000	1,138,000	138,000	61,500	32,900	2,699,340

1921	RGU**	6,620	12,000	21,100	10,500	23,700	34,700	50,100	70,700	65,500	55,700	46,200	23,800	420,620
	CON**	38,900	40,800	43,800	9,320	4,050	52,900	42,900	4,050	207,000	210,000	12,600	18,500	684,820
	RGL**	45,500	52,800	64,900	18,900	27,200	87,100	91,700	74,000	272,000	266,000	58,800	42,300	1,101,200
1922	RGU**	10,700	23,500	21,700	26,700	21,000	19,700	22,400	43,700	37,600	29,200	25,300	18,100	299,600
	CON**	15,900	4,050	4,050	4,050	12,200	74,700	44,600	18,000	4,050	24,100	25,700	20,300	251,700
	RGL**	26,000	27,600	25,800	29,800	32,700	93,900	65,700	60,900	41,600	53,300	51,000	38,400	547,300
1923	RGU**	10,700	19,100	19,600	10,400	13,400	19,600	28,500	82,600	44,400	46,300	18,400	21,700	334,700
	CON**	33,400	41,600	31,400	122,000	17,600	36,400	20,600	114,000	750,000	156,000	76,000	91,900	1,490,900
	RGL**	44,100	60,700	51,000	132,000	30,500	55,500	47,800	196,000	794,000	202,000	94,400	114,000	1,822,000
1924	RGU**	17,100	27,000	24,200	23,600	40,400	19,300	73,900	37,100	42,400	19,200	11,600	16,300	352,100
	CON**	147,000	57,100	42,500	30,800	27,600	34,000	15,800	11,300	78,700	106,000	49,900	46,100	646,800
	RGL**	164,000	84,100	66,700	53,500	67,500	52,800	88,500	47,600	121,000	125,000	61,500	62,400	994,600
1925	RGU**	10,700	12,300	12,900	6,640	14,400	14,400	18,800	74,300	62,400	33,400	13,300	11,400	284,940
	CON**	56,700	48,700	56,100	73,400	148,000	72,900	213,000	601,000	606,000	279,000	110,000	90,200	2,355,000
	RGL**	67,400	61,000	69,000	79,100	162,000	86,800	231,000	675,000	668,000	312,000	123,000	102,000	2,636,300
1926	RGU**	12,500	7,400	11,700	18,400	29,300	23,200	66,400	34,100	40,600	44,000	17,600	18,800	324,000
	CON**	96,500	79,600	68,200	50,600	53,800	52,900	55,300	276,000	294,000	216,000	106,000	93,200	1,442,100
	RGL**	109,000	87,000	79,900	68,100	82,600	75,600	120,000	309,000	335,000	260,000	124,000	112,000	1,762,200
1927	RGU	10,500	10,100	6,120	4,930	6,400	11,700	3,230	38,300	45,400	32,100	26,800	19,000	214,580
	CON	87,500	76,500	80,000	79,700	67,900	74,100	87,200	107,000	107,000	86,900	71,900	88,000	1,013,700
	RGL	98,000	86,600	86,100	84,100	74,000	85,900	89,600	145,000	152,000	119,000	98,700	107,000	1,226,000
1928	RGU	11,600	12,000	5,270	13,200	26,500	3,240	2,640	75,200	29,800	21,400	25,900	18,600	245,350
	CON	89,300	87,700	74,700	62,100	64,300	73,000	106,000	177,000	86,400	95,500	100,000	97,700	1,113,700
	RGL	101,000	99,700	79,900	74,800	90,500	75,900	108,000	252,000	116,000	117,000	126,100	116,000	1,356,800
1929	RGU	10,480	8,820	8,660	4,070	14,990	5,610	9,600	62,580	19,050	39,460	23,930	13,170	220,420
	CON	85,300	81,300	80,800	77,900	82,400	77,800	87,500	106,000	132,000	88,000	72,400	67,700	1,039,100
	RGL	95,800	90,100	89,400	81,400	97,100	83,100	96,300	168,000	151,000	128,000	96,300	80,900	1,257,400
1930	RGU	12,190	10,030	6,690	6,300	5,770	28,610	12,290	41,340	6,650	43,900	13,310	13,620	200,700
	CON	66,100	40,600	24,300	16,500	17,400	23,300	51,100	155,000	10,400	47,200	29,000	28,700	509,600
	RGL	78,300	50,600	30,900	22,300	22,800	51,600	62,600	196,000	17,000	91,200	42,300	42,300	707,900
1931	RGU	10,090	10,170	7,740	26,830	23,440	3,430	17,380	31,450	17,780	14,900	10,240	10,280	183,730
	CON	20,300	29,100	46,500	50,700	49,100	57,100	82,100	86,800	59,200	66,000	55,200	59,600	661,700
	RGL	30,400	39,300	54,200	77,000	72,200	60,200	98,700	118,000	77,000	80,900	65,400	69,900	843,200
1932	RGU	8,860	10,040	10,160	1,520	2,170	830	6,700	34,000	36,000	61,480	22,220	21,330	215,310
	CON	50,900	52,100	44,700	29,300	18,200	9,720	27,800	136,000	505,000	798,000	62,600	50,900	1,785,220
	RGL	59,800	62,100	54,900	30,700	19,900	10,100	34,400	170,000	542,000	859,000	84,800	72,200	1,999,900
1933	RGU	14,300	13,940	11,890	3,850	4,340	14,590	20,000	11,810	32,670	22,870	17,290	14,790	182,340
	CON	50,700	39,330	43,700	48,600	35,700	91,900	61,100	85,200	533,000	200,000	73,200	69,400	1,331,800
	RGL	65,000	53,200	55,400	51,500	39,800	106,000	80,100	96,400	566,000	223,000	90,500	84,200	1,511,000
1934	RGU	11,700	15,600	14,500	4,090	1,800	928	130	2,170	3,140	0	0	374	54,315
	CON	64,500	62,300	59,200	49,500	48,200	58,100	61,600	43,500	38,700	41,000	45,500	44,100	616,200
	RGL	76,200	77,900	73,600	53,000	49,700	58,700	60,800	45,200	41,800	41,000	45,500	44,500	667,900

† Flow was initially impounded upstream at La Boquilla Reservoir on the Rio Conchos in 1914
@ Flow was initially impounded upstream at Elephant Butte Reservoir on the Rio Grande in 1915

TABLE 1 cont.

Year	Station	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total
	RGU	644	1,420	285	0	0	9,780	3,420	13,600	68,500	22,800	6,920	9,310	136,679
1935	CON	44,600	32,500	20,900	5,000	3,950	52,800	42,700	60,400	249,000	116,000	45,000	26,600	699,450
	RGL	42,200	33,900	21,200	4,460	3,660	62,300	45,300	73,500	318,000	139,000	51,900	35,900	834,320
	RGU	9,690	6,740	4,560	201	1,400	965	2,810	12,000	66,000	25,200	11,300	12,900	153,766
1936	CON	24,100	31,800	24,200	11,600	11,300	8,720	22,200	39,600	329,000	99,800	52,100	60,100	714,520
	RGL	33,800	38,500	28,800	11,000	12,300	9,250	23,900	50,900	395,000	125,000	63,400	73,000	864,850
	RGU	8,330	5,060	1,830	307	132	13,800	7,350	9,800.	38,600	36,400	15,900	15,400	152,909
1937	CON	48,200	46,600	35,400	11,800	20,300	36,000	37,700	29,000	165,000	70,600	30,500	48,600	579,700
	RGL	56,500	51,700	37,200	11,200	19,900	49,300	43,800	38,000	204,000	107,000	46,400	64,000	729,000
	RGU*	13,100	12,200	9,990	7,800	4,880	9,460	63,900	10,900	59,200	12,000	10,500	9,840	223,770
1938	CON	66,300	40,000	27,600	8,650	13,700	74,800	502,000	246,000	1,141,000	170,000	87,100	59,700	2,431,850
	RGL	74,400	52,200	37,600	15,600	18,100	83,800	564,000	256,000	1,200,000	183,000	97,600	69,500	2,651,800
	RGU	11,500	9,780	6,350	1,500	2,530	2,490	2,070	27,700	13,400	12,600	11,100	12,500	113,520
1939	CON	57,700	60,200	48,600	17,700	13,700	17,300	44,500	185,000	43,500	58,600	59,300	43,200	649,300
	RGL	69,200	70,000	55,000	18,400	15,800	19,400	45,600	212,000	56,800	71,200	70,400	55,700	759,500
	RGU	12,400	10,000	4,070	647	1,420	9,230	5,140	31,900	14,400	8,730	7,600	7,600	113,137
1940	CON	49,900	43,100	27,600	12,900	32,200	49,900	81,600	92,300	74,400	34,600	30,200	23,800	552,500
	RGL	62,300	53,100	31,600	12,700	33,200	58,700	85,700	124,000	88,800	43,400	37,800	31,400	662,700
	RGU	8,350	6,830	4,150	8,4450	39,500	40,000	42,700	69,800	76,600	105,000	34,500	28,900	463,780
1941	CON	31,500	51,300	34,000	49,500	138,000	49,800	141,000	234,000	442,000	759,000	106,000	67,400	2,103,500
	RGL	39,800	58,200	38,100	57,200	177,000	89,500	183,000	304,000	518,000	864,000	141,000	96,300	2,566,100
	RGU	21,800	40,800	39,100	41,600	240,000	216,000	156,000	133,000	151,000	79,200	27,300	30,900	1,176,700
1942	CON	61,500	43,600	47,900	24,200	30,900	51,000	50,000	385,000	1,173,000	241,000	109,000	78,400	2,295,500
	RGL	83,300	84,400	87,000	65,000	270,000	267,000	204,000	517,000	1,324,000	320,000	136,000	109,000	3,466,700
	RGU	24,400	19,200	22,600	9,420	13,000	18,800	42,200	2,790	12,400	25,200	16,000	20,600	226,610
1943	CON	62,700	58,900	64,600	24,300	28,200	46,900	185,000	27,000	74,400	139,000	37,000	54,300	802,600
	RGL	87,000	78,000	87,100	33,100	40,900	65,500	226,000	29,300	87,100	164,000	53,000	74,900	1,025,900
	RGU	19,800	15,400	14,600	5,060	7,780	16,800	22,100*	39,900*	36,100	26,600	19,600	19,400	243,140
1944	CON	59,700	36,300	39,100	23,100	16,700	15,200	42,200	23,700	374,000	110,000	37,700	35,600	813,300
	RGL	79,500	51,600	53,700	27,800	24,300	31,900	63,800	63,400	410,000	136,000	57,300*	55,000	
	RGU	17,000	13,400	8,230	14,800	2,110	1,940	32,000	1,090	602	55,800	19,500	22,200	188,672
1945	CON	54,100	40,700	32,000	14,400	8,420	13,300	198,000	30,400	6,770	196,000	60.700	22,200	676,990
	RGL	71,100	54,100	40,300	29,100	10,500	15,200	230,000	31,500	7,370	252,000	80,200	44,400	865,770
	RGU	19,900	12,000	8,040	895	2,640	446	6,990	128*	20,800	39,100	10,100	12,400	133,439
1946	CON	43,700	36,500	40,100	27,700	17,400	21,400	46,900	18,300	214,000	164,000	53,100	42,800	725,900
	RGL	63,600	48,500	48,100	28,500	20,100	21,800	53,800	18,400	235,000	203,000	63,200	55,200	859,200
	RGU	14,800	10,300	3,940	405	5,320	218*	13*	7,270*	7,420*	604	552	3,880	54,722*
1947	CON	56,600	48,000	33,700	8,000	14,000	12,800	8,890	123,000	188,000	32,200	59,900	50,400	636,490
	RGL	71,400	58,300	37,700	8,410	19,300	13,100	8,910	131,000	196,000	33,800	60,400	54,300	692,620
	RGU	4,630	2,570	288	82	4*	3,680	648*	2,540	2,900	3,760	4,850	5,780	31,732
1948	CON @	39,200	43,200	46,700	12,500	15,600	19,300	32,900	22,400	27,300	35,600	44,700	31,900	371,000
	RGL	43,800	45,800	47,000	12,200	15,500	22,800	32,900	24,600	30,200	39,400	49,600	37,700	401,500

* Flow was initially impounded upstream at Caballo Reservoir on the Rio Grande in February, 1938
@ Flow was initially impounded upstream at Madero Reservoir on the Rio Conchos in July, 1948

	RGU	11,200	7,480	1,410	312	1,500	592	2,720	12,800	34,900	13,200	12,100	10,300	108,514
1949	CON	33,600	61,100	51,000	15,000	16,800	13,300	71,400	131,000	97,200	80,300	63,800	45,800	680,300
	RGL	47,600	68,600	52,400	14,800	18,000	13,700	73,500	144,000	132,000	93,500	75,900	56,100	790,100
	RGU	9,450	3,640	463*	69**	0	4,710	25,100	12,100*	14,100	19,700	6,370	5,510	101,212
1950	CON	52,200	48,500	48,900	18,000	19,500	41,300	101,000	67,200	98,800*	73,700*	41,800	38,000	648,900*
	RGL	61,600	52,200	49,300	17,600	19,200	45,700*	126,000	78,900	113,000*	93,500*	48,200	43,500	748,700*
	RGU	3,350	1,010	91**	18**	296	574	4,610	1,700	5,600	.6	0	0	17,249.8
1951	CON	31,300	52,900	39,200	16,600	31,600	37,400	48,700	24,800	20,600	20,100	20,700	19,500	363,400
	RGL	34,700	53,900	39,200	16,200	31,600	37,700	52,900	26,100	26,100	20,100	20,700	19,500	378,700
	RGU	0	0	0	257	1**	2,430	9,990	120	0	0	0	0	12,798
1952	CON	17,700	13,600	9,970	3,220	5,050	47,600	201,000	19,000	12,400	12,200	10,600	11,600	363,940
	RGL	17,700	13,600	9,790	2,930	4,530	49,600	211,000	18,400	12,100	12,000	10,600	11,600	373,850
	RGU	0	0	0	0	0	348	4,920	3,220	438	159	0	0	9,085
1953	CON	14,300	11,3 0	8,560	855	2,240	4,830	13,300	7,660	23,500	5,890	9,510	9,940	111,885
	RGL	14,300	11,300	8,170	464	1,760	4,540	17,600	10,200	23,900	6,050	9,510	9,940	117,734
	RGU	0	0	0	289	1,650	6,360	3,650	24,100	3,960*	9,340	1	0	49,350
1954	CON	11,500#	10,600#	5,410#	925	1,560	760	14,620	131,900	50,020	25,100	13,820	10,330	276,545
	RGL	11,600	10,700	5,400	1,250	4,110	7,210	19,200	158,000*	55,200	37,900	15,700	12,000	338,270*
	RGU	42	0	0	19	0	226	2,240	4,030	6,830	10,900	5	0	24,292
1955	CON	13,840	11,760	6,350	281	319	1,200	68,520*	147,300*	70,400	126,200	27,920	18,580	492,670
	RGL	14,900	13,300	7,710	309	219	2,600	79,900*	163,000*	94,900	142,000*	31,100	21,600	571,538*
	RGU	0	0	0	0	0	0	49.4	2,350	0	115	0	0	2,514.4
1956	CON	16,170	18,850	12,730	2,830	6,420	11,250	9,770	24,250	28,960	20,310	20,460	19,030	191,030
	RGL^T	16,170	18,850	12,730	2,830	6,420	11,250	9,819.4	26,600	28,960	20,425	20,460	19,030	193,544.4
	RGU	0	0	0	186	1,120	1,580	108	29.4	692	2,480	0	0	6,195.4
1957	CON	19,930	21,140	12,720	7,040	27,180	21,290	13,410	44,220	19,470	73,890	22,590	20,950	303,830
	RGL	22,900	26,700	14,200	8,100	31,800	23,000*	15,500	50,800	23,500	80,300*	24,100	22,200	343,100*
	RGU	0	233	0	0	3.8*	106*	306*	3,110	19,300	13,900	609*	36.3	37,604.1
1958	CON	17,540	15,620	9,270	1,430	3,870	7,660	2,190	15,100	686,400*	971,300*	107,400	55,160	1,892,940
	RGL	18,000	14,800	9,300	1,450	2,530	9,100	4,680	20,600	582,000	1,051,000	111,100	51,700	1,876,260
	RGU	0	0	0	0	91.2	1,220	1,580	3,190	410	729	0	0	7,220.2
1959	CON	36,940	19,030	19,050	17,350	22,600	17,650	52,780	123,600	138,700	27,420	28,060	29,150	532,330
	RGL	37,200	22,900	20,100	18,200	25,800	23,100	61,200*	127,000*	127,000	30,600	30,600	31,400	555,100
	RGU	0	0	0	0	0	0	8,540	9,080	1,950	5,990	3,390	4,180	33,130
1960	CON	51,750	72,270	51,530	22,650	16,070	20,410	130,000	201,600	112,100	36,100	51,200	62,380	828,060
	RGL^T	51,750	72,270	51,530	22,650	16,070	20,410	138,540	210,680	114,050	42,090	54,590	66,560	861,190
	RGU	3,400	1,140	1.8	0	2,930	3,870	744	3,120	370	713	.6	0	16,289.4
1961	CON	59,250	41,550	32,550	13,520	20,070	51,770	55,290	66,790	45,140	45,400	29,260	27,840	488,430
	RGL^T	62,650	42,690	32,551.8	13,520	23,000	55,640	56,034	69,910	45,510	46,113	29,260.6	27,840	504.719.4
	RGU	0	0	0	0	0	69	2,932	3,382	11,854	8,599	4,159	4,485	35,480
1962	CON	27,151	20,527	20,050	9,468	9,067	18,389	61,570	16,097	102,434	67,482	32,410	33,062	417,707
	RGL^T	27,151	20,527	20,050	9,468	9,067	18,458	64,502	19,479	114,288	76,081	36,569	37,547	453,187

T = Totaled from RGU and CON.
#Based on discharged at Lower Presidio and estimated irrigated diversions.

TABLE 1 cont.

		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total
	RGU	1,756	107	0	0	322	0	47.4	6,091	8,525	286	664	364	18,162.4
1963	CON	28,352	18,817	15,264	10,718	19,378	28,209	52,969	63,038	79,578	31,765	30,554	23,997	402,639
	RGL^T	30,108	18,924	15,264	10,718	19,700	28,209	53,016.4	69,129	88,103	32,051	31,218	24,361	420,801.4
	RGU	0	0	0	0	146	71	1.8	0	733	0	0	0	951.8
1964	CON	20,295	23,642	24,762	11,682	17,411	64,219	25,036	34,876	46,734	34,175	28,926	29,216	360,974
	RGL^T	20,295	23,642	24,762	11,682	17,557	64,290	25,037.8	34,876	47,467	34,175	28,926	29,216	361,925.8
	RGU	0	0	0	0	0	7.1	0	282	2,070	0	0	0	2,359.1
1965	CON	30,197	31,703	25,168	12,154	13,088	21,805	12,738	45,050	65,293	30,372	35,968	26,095	349,631
	RGL^T	30,197	31,703	25,168	12,154	13,088	21,812.1	12,738	45,332	67,363	30,372	35,968	26,095	351,990.1
	RGU	0	0	0	0	0	1,201	814	5,589	24,572	2,853	133	29.4	35,191.4
1966	CON	20,959	18,260	12,275	6,498	14,955	52,883	40,937	275,140	608,140	85,546	40,066	28,803	1,204,462
	RGL^T	20,959	18,260	12,275	6,498	14,955	54,084	41,751	280,729	632,712	88,399	40,199	28,832.4	1,239,653.4
	RGU	4.8	0	0	0	0	374	333	964	1,568	146	0	0	3,389.8
1967	CON	30,405	22,813	22,573	12,635	19,436	62,585	54,145	45,578	135,993	59,244	44,857	30,743	541,007
	RGL^T	30,409.8	22,813	22,573	12,635	19,436	62,959	54,478	46,542	137,561	39,390	44,857	30,743	544,396.8
	RGU	0	0	0	1	0	0	8,407	2,829	4,211	445	106	178	16,177
1968	CON	19,879	3,336	4,171	9,235	10,932	6,008	93,705	115,918	468,680	189,837	125,311	35,053	1,082,065
	RGL	19,879	3,336	4,171	9,236	10,932	6,008	102,112	118,747	472,891	190,282	125,417	35,231	1,098,242
	RGU	0.8	0	0	0	20	851	861	33.3	766	1.4	61.7	1,106	3,701.2
1969	CON	131,293	124,386	130,298	76,357	26,730	47,101	77,426	31,728	46,959	45,537	33,659	30,071	801,545
	RGL^T	131,293.8	124,386	130,298	76,357	26,750	47,952	78,287	31,761.3	47,725	45,538.4	33,720.7	31,177	805,246.2
	RGU	88.3	1	0	0	0	1,063	344	2,651	7,267	16,398	5,171	4,695	43,678.3
1970	CON	26,134	22,659	18,214	11,876	12,852	28,680	23,833	43,332	96,299	149,785	82,927	47,841	564,432
	RGL^T	26,222.3	22,660	18,214	11,876	12,852	29,743	24,177	51,983	103,566	166,183	88,098	52,536	608,110.3
	RGU	3,238	307	17.1	0	0	953	1,362	2,445	1,746	13,397	291	669	24,425.1
1971	CON	28,642	28,355	27,011	19,059	19,105	29,066	29,044	91,332	64,055	69,550	7,484	51,114	463,767
	RGL^T	31,880	28,662	27,028.1	19,059	19,105	30,019	30,406	93,777	65,751	82,947	7,775	51,783	488,192.1
	RGU	240	7.5	0	0	198	3,133	4,084	8,466	56,577	3,825	1,893	961	79,384.5
1972	CON	93,909	28,179	47,161	40,507	45,957	57,479	73,771	105,915	263,069	62,361	26,302	24,243	868,853
	RGL^T	94,149	28,186.5	47,161	40,507	46,155	60,612	77,855	114,381	319,646	66,186	28,195	25,204	948,237.5
	RGU	1,054	1,008	342	5.2	0	0	863	2,815	504	0	0	13.5	6,604.7
1973	CON	21,787	16,021	9,767	6,922	20,243	38,274	115,253	243,660	197,367	24,954	23,998	18,408	736,654
	RGL^T	22,841	17,029	10,109	6,927.2	20,243	38,274	116,116	246,475	197,871	24,954	23,998	18,421.5	743,258.7

TABLE 2

UNCONTROLLED RIVER FLOW

From daily records from 19 years (1896 through 1914) immediately upstream from the confluence of the Rio Conchos and the Rio Grande near Presidio, Texas. Data taken from Table 1.

Station	Total Flow 1896-1914 (Acre-Feet)	Average Yearly Flow (Acre-Feet)	Percent of Total Flow Below the Confluence
Rio Conchos	25,770,000	1,356,000	71%
Upper Rio Grande	10,511,000	553,000	29%

TABLE 3

DATA FOR UNCONTROLLED FLOW OF THE UPPER RIO GRANDE

7.8 miles upstream from the confluence with the Rio Conchos near Presidio from daily records taken during a 19-year period (1896 through 1914). Data from Table 1.

Months with flow less than 1,000acre-feet	41
Months with no flow (included above)	30
Consecutive months with no flow 1903-1904	7
Consecutive months with no flow 1900-1901	6

TABLE 4

FLOW OF THE RIO GRANDE: GAGE AND DISCHARGE

0.4 RIVER MILES DOWNSTREAM FROM ALAMITO CR.

(DATA FROM INTERNATIONAL BOUNDARY AND WATER COMMISSION)

Year		January		February		March		April		May		June	
		Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (second-Feet)	Gage (Feet)	Discharge (Second-Feet)
	High	6.36	823	5.81	464.0	5.75	412.0	7.32	1,710.0	8.70	4,120	9.44	5,950.0
1963	Low	5.68	367	5.55	270.0	5.12	97.6	4.98	64.1	5.12	123	5.09	119.0
	Average		531		355.0		257.0		174.0		378		480.0
	High	5.83	554	6.64	1 270.0	6.59	1,230.0	6.33	417.0	10.69	10,600	10.57	6,480.0
1964	Low	5.47	301	5.48	320.0	5.31	218.0	5.22	145.0	5.69	106	N/A	N/A
	Average		382		451.0		426.0		200.0		375		1,160.0
	High	6.54	795	6.69	952.0	6.47	720.0	6.07	375.0	8.16	2,460	8.57	1,160.0
1965	Low	6.08	391	6.08	371.0	5.71	161.0	5.65	130.0	5.67	149	7.27	189.0
	Average		529		581.0		427.0		197.0		218		386.0
	High	9.20	501	9.21	508.0	9.02	3.91	9.12	470.0	11.86	4,190	13.00	6,280.0
1966	Low	8.86	309	8.74	259.0	8.34	1.17	7.63	13.4	8.06	603	8.16	67.8
	Average		379		346.0		2.11		94.1		267		948.0
	High	9.94	1,140	9.69	866.0	10.78	2,570.0	9.05	332.0	9.45	589	13.82	9,890.0
1967	Low	9.03	329	9.04	323.0	8.77	239.0	8.68	158.0	8.76	177	9.11	345.0
	Average		514		445.0		394.0		217.0		307		1,160.0
	High	9.91	699	8.90	121.0	9.09	164.0	10.15	1,010.0	4.35	3,630	1.71	159.0
1968	Low	8.90	109	8.23	29.2	7.89	9.7	8.25	30.8	1.53	100	1.19	20.0
	Average		341		82.5		74.5		185.0		198		99.6
	High	3.71	2,070	3.85	2,380.0	3.77	2,200.0	3.63	1,910.0	3.95	2,620	5.66	7,690.0
1969	Low	3.52	1,700	3.47	1,610.0	2.64	705.0	2.39	506.0	1.98	264	1.55	106.0
	Average		1,900		2,000.0		1,890.0		1,210.0		458		848.0
	High	2.44	528	3.60	1,850.0	2.82	797.0	1.90	231.0	2.49	560	6.20	10,000.0
1970	Low	2.19	377	2.05	303.0	1.79	188.0	1.67	145.0	1.69	152	1.66	141.0
	Average		443		414.0		273.0		183.0		215		422.0
	High	2.56	603	2.59	628.0	2.50	567.0	2.18	372.0	2.26	417	4.96	5,250.0
1971	Low	2.31	447	2.18	372.0	1.99	273.0	1.87	218.0	1.83	203	1.78	184.0
	Average		515		481.0		398.0		283.0		289		385.0
	High	3.62	1,950	2.54	594.0	2.91	867.0	2.71	714.0	5.91	9,130	4.12	3,270.0
1972	Low	2.01	283	2.15	356.0	2.18	371.0	2.42	515.0	2.45	550	2.33	467.0
	Average		1,410		439.0		670.0		603.0		730		965.0
	High	2.26	426	2.21	382.0	2.03	292.0	1.70	154.0	4.78	5,320	3.36	1,520.0
1973	Low	2.15	350	1.98	268.0	1.34	40.7	1.50	87.6	1.54	105	1.60	129.0
	Average		393		317.0		161.0		122.0		329		602.0

July		August		September		October		November		December		Annual	
Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)	Gage (Feet)	Discharge (Second-Feet)
9.07	5,010.0	8.57	4,330	10.22	8,240	7.69	2,420	8.27	3,470	5.88	589	10.22	8,240.0
5.11	126.0	5.42	406	5.57	467	5.51	432	5.50	401	5.58	388	4.98	64.1
	860.0		1,170		1,580		586		552		459		616.0
8.55	3,310.0	8.15	2,800	11.00	8,600	7.19	1,680	6.71	988	6.50	737	11.00	10,600.0
N/A	N/A	5.89	280	5.71	253	6.00	322	6.04	357	6.02	340	N/A	106.0
	434.0		606		869		598		510		495		541.0
10.09	2,990.0	10.16	6,430	11.12	7,410	6.90	864	10.04	1,150	9.30	554	11.12	7,410.0
7.11	64.3	5.70	109	6.01	202	6.23	380	9.06	387	8.91	318	5.65	64.3
	206.0		860		1,180		527		593		441		511.0
12.37	4,900.0	17.67	17,500	17.48	18,600	12.79	7,490	9.79	934	9.52	665	17.67	18,600.0
8.19	104.0	8.35	129	9.90	1,380	9.50	690	9.37	530	9.17	413	7.63	13.4
	703.0		3,750		9,250		1,410		680		507		1,540.0
13.36	8,850.0	11.93	5,060	12.66	6,760	10.62	1,740	10.26	1,130	10.17	994	13.82	9,890.0
9.36	371.0	9.57	394	10.10	900	9.83	597	9.73	542	9.53	364	8.68	158.0
	923.0		775		2,420		930		754		512		778.0
6.80	13,100.0	4.96	5,250	8.66	23,200	5.64	7,620	5.15	5,820	3.65	1,950	8.66	23,200.0
1.22	25.2	3.18	1,250	3.25	1,330	2.55	630	2.55	630	1.72	162	7.89	9.7
	1,750.0		1,910		7,900		2,770		1,910		537		1,470.0
5.38	6,620.0	3.64	1,930	4.97	5,280	3.71	1,120	2.78	766	2.66	678	5.66	7,690.0
1.80	191.0	1.64	134	2.01	283	2.41	508	1.94	249	2.11	334	1.55	106.0
	1,420.0		494		774		661		550		519		1,050.0
5.15	5,820.0	3.91	2,520	5.42	6,770	5.94	8,870	3.61	1,870	3.28	1,290	6.20	10,000.0
1.50	91.1	1.85	210	2.25	411	3.59	1,830	2.60	635	2.24	406	1.50	849.0
	403.0		731		1,720		2,680		1,510		849		822.0
5.30	6,330.0	6.10	9,880	6.04	9,320	6.51	13,000	1.90	231	3.46	1,590	6.51	13,000.0
1.89	226.0	2.21	388	2.00	289	1.88	222	1.56	108	1.58	115	1.56	108.0
	511.0		1,510		1,140		1,760		147		756		685.0
4.68	4,310.0	6.07	10,200	5.84	9,360	4.86	5,600	2.41	521	2.29	435	6.07	10,200.0
2.59	628.0	2.73	763	3.75	2,360	2.40	501	2.28	440	2.22	397	2.01	283.0
	1,130.0		1,730		5,370		1,240		475		420		1,260.0
5.05	6,280.0	5.18	7,110	5.20	6,810	2.35	475	2.52	592	2.31	452	5.20	7,110.0
2.75	775.0	3.52	1,830	2.13	348	2.06	311	2.15	358	1.56	104	1.34	40.7
	2,030.0		4,400		3,570		404		403		323		1,090.0

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APPENDIX 1

LAJITAS MESA MEASURED SECTION

Measured up the southeast side of the southwest face of Lajitas Mesa on June 26, 1964, with hand level and 6-ft steel tape, by John McKnight (1968, measured section 1).

SUMMARY:	**feet**	**feet**
Chisos Formation		
Bee Mountain Member, Tcbm (partial)	45	
undifferentiated, Tc	520	
Alamo Creek Member, Tcac	124	
undifferentiated, Tc	12	
Total	701	701
Jeff Conglomerate, Tj		20
Pen Formation, Kp		base
TOTAL measured thickness:		721

Unit	**Description**	**Thickness in Feet**

CHISOS FORMATION

Top of section is in the Bee Mountain Basalt similar to that described below, but thorougly slumped and covered by talus. Lajitas Mesa is capped by at least 200 ft of Tule Mountain Trachyandesite Porphyry (Tctm); the base is not exposed.

Bee Mountain Member, Tcbm

19. Basalt. Abundant 1 mm trachytic plagioclase phenocrysts in a black, brown-weathering, aphanitic groundmass, speckled with iddingsite; scoriaceous in lower few feet, and slightly vesicular elsewhere. 45
18. Conglomerate. Similar to that of unit 7, but clasts are 80% igneous rock and 20% limestone. 12
17. Sandstone. Thin-bedded; fine- to medium-grained; gray to red-brown. 9
16. Tuff. Nonbedded; gray. 22
15. Tuffaceous sandstone. Thin-bedded; white to light-gray and buff. 10
14. Tuff. Nonbeded; white to buff. 27
13. Tuff. Thin-bedded; white to buff and yellow-brown; contains abundant root holes. 7
12. Tuff. Nonbedded; alternating pale-gray and red-brown layers, 7 to 30 ft thick in lower 50 ft and mostly less than 5 ft thick higher. 205
11. Sandstone and clay. Interbedded in layers mostly less than 1 ft thick; about half is fine- to medium-grained, thin-bedded, gray, calcite-cemented sandstone; the remainder is thin-bedded, red-brown mudstone with gray mottling in the upper 5 ft of the unit; forms cliffs. 22
10. Tuffaceous clay. Nonbedded; pale-gray, friable; forms slope or undercuts beneath interbedded sandstone and shale above. 6
9. Mudstone and sandstone. Intercalated; about 3/4 of unit is thin-bedded, red-brown mudstone; remainder is well-bedded and cross-bedded, medium- to coarse-grained, gray-green to red-brown sandstone that occurs in lenticular channels as much as 5 ft thick; forms cliff. 115
8. Sandstone. Well-bedded, with thicker beds cross-bedded; coarse-grained; gray-green; calcite-cemented; forms cliff. 12
7. Conglomerate. About 2/3 of the coarse clasts are rounded pebble- to cobble-size fragments of micritic limestone, and the rest are angular to rounded pebble- to boulder-size fragments of igneous rock; matrix is calcite-cemented tuffaceous sandstone; sandstone like that in unit 8 forms intercalated lenses as much as 2 ft thick and beds less than 1 foot thick; erodes to a nearly vertical cliff. 17
6. Mudstone. Like that in unit 5; sandstone stringers less than 2 ft thick make up less than 5% of the rock. 22
5. Mudstone and sandstone. Intercalated; mudstone is faintly thin-bedded, red-brown, and makes up about 60% of the rock at the base and 80% at the top; sandstone is thin-bedded and cross-bedded, red-brown and gray-green, coarse- to medium-grained, and occurs in lenses a few inches to 6 ft thick and a few feet to several tens of feet in outcrop length; the sandstone is relatively resistant and erodes to steep cliffs between gentler slopes formed on mudstone. 32
4. Clay. Nonbedded, unctious, dark-blue-gray; crumbly where dry. 3

Alamo Creek Member, Tcac

3. Basalt. See description in text (p. 38-39). 124

undifferentiated Chisos Formation, Tc

2. Muddy sandstone. Contact with conglomerate below is abrupt and flat; thin-bedded and cross-bedded in places, and elsewhere massive; friable; mostly gray-green with pale red-brown mottling, but lower 2 ft is yellow-brown, and upper foot is dark-gray and probably lignitic. 12

JEFF CONGLOMERATE, Tj

1. Conglomerate. Rounded pebbles and cobbles of micritic limestone and cherty limestone, and pebbles of chert in a matrix of brown calcite-cemented sandstone and Pen-like clay; contains no volcanic rock fragments; largest cobble is about 6 in across. 20

TOTAL: 721

Base of section at top of Pen Formation, here gypsiferous clay more than 100 ft thick.

APPENDIX 2

SOUTH LAJITAS MESA MEASURED SECTION

Measured up the west face of South Lajitas Mesa near the northwest corner, on June 28, 1964, with hand level and 6-ft steel tape, by John McKnight (1968, measured section 2).

SUMMARY:	**feet**
Chisos Formation	
Tule Mountain Member, Tctm	68
basalt, Tcb	3
undifferentiated, Tc	99
Mule Ear Spring Member, Tcm	5
undifferentiated, Tc	23
Bee Mountain Member, Tcbm	190
undifferentiated, Tc	204
Total:	592

Unit	**Description**	**Thickness in feet**
	CHISOS FORMATION	
	Top of South Lajitas Mesa. To the southeast, near the middle of the west edge, the Tule Mountain Trachyandesite Porphyry is overlain by 10 ft of white tuff, and by the Mitchell Mesa Tuff, which is 5 ft thick.	
	Tule Mountain Member, Tctm	
17.	Trachyandesite porphyry. Corroded plagioclase phenocrysts in a red-brown aphanitic matrix with green and olive-green patches of celandonitic alteration products; vesicles are occupied by calcite, celadonite, and chalcedony; weathers to spalls along swirled flow structure, particularly near top of flow; thickness ranges between 50 and 150 ft at different places along the west side of the mesa.	68
	basalt, Tcb	
16.	Basalt. Aphanitic; red-brown weathering, dark-gray, with specks of iddingsite.	3
	undifferentiated Chisos Formation, Tc	
15.	Tuff. Thick-bedded, interbedded red-brown and yellow; upper 3 ft is baked zone beneath overlying basalt; upper 3 in is microcrystal tuff described in text, here porcelaneous and thoroughly silicified; forms cliff.	28
14.	Tuff. Nonbedded; variegated pink and white to pale-green.	8
13.	Mudstone. Nonbedded; pale-green, weathers light-brown.	1
12.	Tuff. Nonbedded; buff.	19
11.	Tuff. Well-bedded from less than 1 in to 6 in thick; some beds are sandy tuff or tuffaceous sandstone; gray; weathers buff.	6
10.	Tuff. Mostly nonbedded and buff; a few 1-ft layers are bedded sandy tuff and contain autoclastic pebbles up to 1 in across; a 4-ft layer of nonbedded pink tuff occurs 5 ft below the top.	36
	Mule Ear Spring Member, Tcm	
9.	Tuff. Nonwelded; pumiceous; porcelaneous; red-brown.	5
	undifferentiated Chisos Formation, Tc	
8.	Tuff. Thick-bedded; white to pale-gray-green.	23
	Bee Mountain Member, Tcbm	
7.	Basalt. See discussion in text (p. 41-43).	190
	undifferentiated Chisos Formation, Tc	
6.	Tuffaceous siltstone. Thin-bedded; pale- to dark-green; weathers red-brown; forms cap rock above steep cliffs cut in nonresistant tuff below.	5
5.	Tuff. Nonbedded; mostly buff, but with pale-gray and red-brown variegations.	109
4.	Tuff. Thin-bedded; mostly pale-green, but a few layers are buff or red-brown; some layers contain autoclastic pebbles as much as 1 in across.	23
3.	Tuff. Nonbedded; mostly buff near base; upper 2/3 is mostly red-brown, and upper foot is pale-green.	40
2.	Tuff. Thin-bedded; pale-green; weathers buff; contains numerous root holes; forms slope but is cap rock of nearly vertical cliffs below.	14
1.	Tuff. Nonbedded; mostly buff with abundant root holes; a 1-ft layer 6 ft above the base is red-brown and devoid of root holes; a 3-in stringer at 9 ft is a fine pebble conglomerate of limestone and volcanic rock fragments.	13
	Total	592

Base of section is observed in a covered interval between tuff (above) and alluvium of Contrabando Creek (below). From comparison with section exposed several thousand feet to south across several faults, about 200 ft of Chisos tuff, sandstone, and conglomerate underlie the section here; Jeff Conglomerate at the base of the Chisos is about 13 ft thick and rests unconformably on upper Boquillas or lower Pen strata.

APPENDIX 3

PANTHER CANYON MEASURED SECTIONS

Measured at the mouth of Panther Canyon, west of Santana Mesa on August 27, 1963 and January 12, 1965, with hand level and 6-ft steel tape, by John McKnight (1968, measured section 5).

SUMMARY:		feet	feet
Santana Tuff, Ts			559
Fresno Formation			
undifferentiated, Tf		24	
latite porphyry, Tflp		220	
undifferentiated, Tf		211	
	Total	455	455
	Total measured thickness:		1014

Unit	Description	Thickness in feet

This part of the section is measured up the northwest wall at the mouth of Panther Canyon.

SANTANA TUFF, Ts

Composition is essentially the same from base to top: pumiceous vitric-crystal tuff with abundant glassy sanidine crystals; the tuff differs in color, induration, jointing, weathering, and foliation caused by differences in devitrification, deuteric alteration of dark minerals, formation of vapor-phase minerals, and welding. All but unit 27 and part of unit 26 are probably in the zone of vapor-phase crystallization. Units are gradational unless otherwise stated.

27. Inferred nonwelded tuff removed by erosion. Massive, white, friable; weathers to rounded forms with caves a few feet across; thickness and appearance approximated by comparison with exposures 2 miles to east on south edge of Madera Graben, north of east end of Santana Mesa where top is exposed beneath Trlb basalt. 40

Top of Mesa

26. Slightly-welded to nonwelded tuff. Friable, massive, dull-gray to white; less resistant than units below—forms sloping rounded bluff. 101
25. Moderately-welded tuff. Well indurated, dull-pink to cream, moderately eutaxitic tuff; horizontally and vertically jointed; weathers to angular blocks probably central part of a cooling unit including part of unit 24 (below) and units 26 and 27 (above). 23
24. Slightly-welded tuff. Massive, slightly friable light-gray with faint eutaxitic structure imparted in outcrop by slightly flattened pumice fragments; weathers to rounded blocks. 54
23. Nonwelded to slightly-welded tuff. Massive, slightly friable, white to gray, with nonflattened or very slightly flattened pumice fragments; lower and upper contacts gradational; center is least welded if at all. 34
22. Moderately- and thoroughly-welded tuff. Similar to unit 20 (below). 52
21. Thoroughly-welded tuff. Similar to that of unit 19 (below). 12
20. Moderately- and thoroughly-welded tuff. Red-brown and porcelaneous in alternating 5- to 30-ft layers with moderate and intense eutaxitic structure; prominent horizontal joints mostly spaced 1 to 3 ft apart but ranging from 1 in to 11 ft; less prominent vertical jointing spaced mostly at intervals of a foot or less promotes formation of blocky talus; unit is relatively nonresistant. Probably several ash flows. 124
19. Thoroughly-welded tuff. Red-brown, porcelaneous, intensely eutaxitic with irregular jointing; weathers to rounded boulders. The unit may be a single ash flow or it may be entablature of a single cooling unit including 17 and 18 (below). 99
18. Thoroughly-welded tuff. Massive, cliff-forming, porcelaneous, orange to dark-red-brown and intensely eutaxitic with columnar joints 6 in to 4 ft across; includes 6-in covered contact zone at base; lowest exposed foot is orange; may be a second ash flow above 17 (below), upper part of a single ash flow including 17, or basal collonade of a single cooling unit including measured units 17, 18, 19, and part of 20. 13
17. Thoroughly-welded tuff. Light-brown and friable, probably devitrified, with flattened fingered pumice fragments, streaked dull orange and glassy black, giving the rock intense eutaxitic structure; prominent horizontal jointing at intervals of a few inches to several feet; forms slope; induration increases upward; upper foot slightly porcelaneous. 7

FRESNO FORMATION
undifferentiated, Tf

16. Tuff. Vitric ash-fall, light-gray and friable with less than 1% biotite flakes. 1
15. Conglomerate. Contains boulders of latite and latite porphyry as much as 3 ft across; matrix is calcite-cemented medium- to coarse-grained volcanic arenite. 23

Offset 300 ft north at the mouth of Panther Canyon, up northwest wall. Rest of the section is measured up the west end of Santana Mesa.

latite porphyry, Tflp

14.	Trachyandesite porphyry (end member of latite series). Resembles Tule Mountain Trachyandesite Porphyry—corroded rhombic plagioclase phenocrysts in a red-brown, green-speckled, aphanitic matrix; weathers along swirled flow structure; vesicles and amygdules of chalcedony and calcite abundant near base and top, and sparse elsewhere.	220

undiferentiated, Tf

13.	Tuff. Massive; pale-red-brown.	1
12.	Tuffaceous sandstone. Massive; gray.	3
11.	Tuff. Massive; gray; friable.	2
10.	Tuff. Nonbedded to faintly-bedded; gray; contains a few layers and lenses of conglomerate of pebble-size fragments of volcanic rock in a matrix of tuffaceous sandstone.	45
9.	Tuff. Faintly-bedded and cross-bedded; gray.	41
8.	Tuff. Massive; white; friable; forms slope.	11
7.	Tuff. Thick-bedded; mottled dark- and light-gray.	40
6.	Tuff. Festoon cross-bedded; pale-gray.	19
5.	Tuff. Massive; gray.	3
4.	Tuff. Interbedded; pale-red-brown and pale-brownish-green; abundant pebble-size nodules; abundant root holes.	13
3.	Tuff. Faintly cross-bedded to nonbedded; white; ½ ft at base has pebble-size calcite-cemented nodules.	15
2.	Tuff. Festoon cross-bedded (3-ft maximum amplitude); white.	6
1.	Tuff. Nonbedded; pale-gray.	12
	Total measured thickness:	**1,014**

Base of the section is in the alluvium of Panther Creek.

APPENDIX 4

BOLSON-FILL SEDIMENTS IN THE PRESIDIO AND REDFORD BOLSONS (from Groat 1972: 7-25)

BASIN-MARGIN FACIES

Definition and Occurrence

The basin-margin facies is that part of the bolson fill consisting chiefly of interbedded conglomerate and sandstone, where conglomerate is more than 10% and mudstone less than 10% of the exposed rock. The sandstone-conglomerate lithosome is the only lithosome in the basin-margin facies, hence the two names are used interchangeably.

Rocks of this facies crop out along the flanks of the bordering mountains and extend into the basin from less than 1 mile to nearly 3 miles. There are excellent exposures near the mountains in the canyons of the major sidestreams, notably Alamito, Cibolo, Spencer, Pinto, Hot Springs, and Sandiguela Creeks. The road to the Gonzalez ranch and the Pinto Canyon road afford easy access to exposures of the basin-margin facies. There are also good exposures in Mexico west of the river road in the area north of San Antonio.

There are areas in the relatively narrow Redford Bolson where the basin-margin facies occupies the entire width of the bolson. There are also places in the Redford Bolson and in Mexico where this facies is not present adjacent to the mountains; in these places the basin-center facies extends from the axis of the basin up to the mountains.

Description

The general makeup of rock types in the basin-margin facies is sandy conglomerate, with subordinate amounts of conglomeratic sandstone, nearest the mountain front, grading to sandstone and slightly pebbly sandstone with minor interbedded small- and medium-pebble conglomerate toward the basin center. Variations are present, but the conglomerate and sandstone are characterized by:

(1) Gradation and irregular variation in texture between conglomerate and sandstone, especially near the bordering mountains.

(2) Lack of distinct bedding and sedimentary structures near the basin margin.

(3) Poor sorting in general and within each of the textural classes (gravel, sand, mud).

(4) Dominance of a small- to medium-pebble mode in the conglomerate, even near the mountains, with a general decrease in mean and largest grain size toward the basin center.

(5) Gravel clasts of local origin: The gravel clasts are all derived from rocks that crop out in the adjacent mountains and are lithologically the same as gravel being transported from these mountains by modern streams.

(6) Pink color when viewed from a distance and various shades of pink, brown, orange brown, and gray in hand specimen.

(7) A rolling, hilly topography with a coarse drainage texture.

The conglomerate of a basin-margin facies is without exception sandy, and the sandstone, especially near the bordering mountains, is nearly all at least slightly conglomeratic; both conglomerate and sandstone commonly contain 2 to 30 percent mud. The sorting of the whole rock is necessarily poor, therefore, and the sorting within each of the texturally mature conglomerate is present but is much less abundant than the very sandy, commonly muddy conglomerates.

Near the basin margins, textural boundaries between sandstone and conglomerate are gradational and irregular; they can best be described in terms of gradational modal shifts rather than as the interbedding of distinct textural types. In addition to gradational relationships, most sandstone beds contain lenses and stringers of more conglomeratic material and vice versa. The lack of distinct bedding in these areas is due to gradational rather than sharp boundaries between textural types.

Bedding, obscure or absent near the basin margin, becomes more distinct toward the basin center as pebbles decrease and some mudstone is interbedded with sandy pebble conglomerate. The "cleaner" sandstone in these areas contains some trough and foreset cross-stratification, although sedimentary structures are not common in any part of the basin-margin facies. The only sedimentary structures noted are crude trough and foreset crossbeds associated with channels.

The most abundant gravel clasts in the basin-margin conglomerate, even near the bordering mountains, are small, medium, and large pebbles. Cobbles and small boulders are present in some parts of the fill adjacent to the mountains, but the mode and median gravel size are in the pebble-size class. Away from the mountains toward the basin center, the amount and size of material coarser than small to medium pebbles decrease and sandiness increases. The thickness and distinctiveness of the interbedded sandstone also increase as the median size of gravel clasts decreases.

Pebble lithologies were noted at more than 50 localities in the conglomerate and conglomeratic sandstone of the basin-margin facies, and all rock types were from the bordering mountains. The riebeckite rhyolite in the bolson-fill, terrace, and modern gravels in and along Alamito Creek is from the outcrop of this rock in the Cienega Mountains. The same relationship is present near Pinto Creek where the distinctive Brite Ignimbrite is a constituent of bolson conglomerate and modern sidestream gravel.

An overall pinkish hue is characteristic of the bolson fill as a whole; individual beds, however, exhibit a range of colors including green, gold, brown, orange, tan, gray, and various shades and combinations of these. The conglomerate and sandstone are likewise characterized by a pink hue with orange brown, pink and gray dominant. The pink and orange-brown color is directly related to the presence of mud in the matrix; when mud is less than about 1 percent of the rock the rock color is generally gray. The pink or orange-brown color is associated with very fine silt and clay grains and aggregates of these, or as hematite (?) coatings on these grains. The hematite (?) dissolves in cold, dilute hydrochloric acid; HCl also breaks down aggregates of the grains, suggesting that some hematite (?) is associated with the calcium carbonate cement.

Most conglomerate and sandstone are well indurated; muddy sand matrix and calcite, in varying proportions, are the binding agents. Conglomerate beds are more resistant than interbedded sandstone, especially in areas where mud, rather than calcite, is the binder. Calcite cement is most common in rock types in the Hot Springs and Pinto Canyon areas where deep, narrow canyons have been cut into the resistant conglomerate and sandstone. Calcite cement is also more common where limestone clasts are present in the conglomerate.

Most first-cycle gravel clasts in the bolson fill are subangular to angular, especially those in the modal pebble class. Exceptions are scattered subround to round tuff and limestone pebbles and small cobbles. The proximity of most bolson-fill conglomerate to the mountain blocks from which it was derived, dictates a short transport distance which precludes rounding of any but the least resistant of clasts.

The conglomerate and sandstone of the basin-margin facies lap onto the bedrock of the adjacent mountains; in places they are in fault contact. The contact is not exposed over large areas except along Bofecillos Creek in the Redford Bolson. Where both types of contact are present in one area, faulting contemporaneous with deposition of the fill is indicated.

The bolson fill adjacent to the bordering mountains is not everywhere conglomerate. Where the large unnamed wash enters the Redford Bolson from the Bofecillos Mountains about 1.2 miles south of Auras Creek, sandstone, mudstone, and minor sandy small-pebble conglomerate are in fault contact with volcanic rock. Mudstone, or mudstone interbedded with sandstone adjacent to the bordering mountain blocks, is not widespread, but it has been reported by Strain (1964:28) in the Hueco Bolson. In technically active areas of modern bolsons, such as Death Valley and Panamint Valley, California, muds are being deposited against mountain blocks. As faulting occurs along one side of a valley or graben, the raised borderland sheds increased amounts of detritus, forcing the locus of deposition of fine-grained sediments against the opposite valley side.

Environment of Deposition

The following characteristics of the conglomerate and sandstone of the basin-margin facies indicate that they are alluvial-fan deposits:

1. Location along the basin margin adjacent to mountain blocks.
2. Gravel clasts derived from the adjacent mountains.
3. Dominance of sandy conglomerate and conglomeratic sandstone, poor sorting, indistinct and irregular bedding, irregular and rapid textural changes, crude scours, and lack of any sedimentary structures except scattered trough crossbeds and crude foresets.

These characteristics are shared by sand and gravel on moderl alluvial fans throughout the Mojave Desert of California. Denny (1940:687) described similar deposits in the Santa Fe Formation in the Española Valley, New Mexico; he ascribed them to alluvial-fan origin for many of the same reasons outlined above. Alluvial-fan deposits described by Blissenback (1954) and Bull (1963), among others, are also similar to the conglomerate and sandstone of the basin-margin facies. Lawson (1913) designated similar deposits he observed on active alluvial fans "fanglomerates," a term applicable to the conglomerate of the bolson fill.

BASIN-CENTER FACIES

Definition and Occurrence

The conglomerate and sandstone of the basin-margin facies grade laterally into interbedded sandstone and mudstone, and in some areas to mudstone, toward the basin center. This comparatively fine-grained part of the bolson fill is the basin-center facies; the boundary is drawn where conglomerate is less than 10% of the section. The basin-center facies is subdivided into a mudstone-sandstone lithosome and a mudstone lithosome. The mudstone lithosome includes all basin-fill deposits in which conglomerate plus sandstone is less than 10%.

Rocks of the basin-center facies crop out over a much larger area than rocks of the basin-margin facies. Exposures are numerous along the many washes tributary to the Rio Grande; there are also many badland areas where exposure is widespread, but detail is obscured by slopewash and a mud-cracked crust. The "pinkish" deposits clearly visible north of Farm Road 170 between Cibolo Creek and Pinto Creek, and west of the Rio Grande in Mexico between Vado de Piedra and Barrancos, are mudstone, with some interbedded sandstone, of the basin-center facies.

Mudstone-Sandstone Lithosome

The zone of lateral gradation between conglomerate and sandstone of the basin-margin facies and interbedded mudstone and sandstone of the basin-center facies is a few hundred yards to nearly a mile wide. In this zone conglomerate decreases in abundance, becoming very sandy and thin bedded; it is succeeded by small pebbly and granular sandstone in the marginal areas of the basin-center facies. Farther toward the basin center, mudstone beds are more common, and sandstone beds are gravel-free, better sorted, and finer grained. Except for some areas in the Redford Bolson, the mudstone-sandstone lithosome does not contain interbedded conglomerate on the basin-center side of the transition zone.

Brown to dark orange-brown mudstone and light brown to buff siltstone are the dominant rock types throughout this lithosome; sandstone generally makes up only about 20 to 40% of the section except near the northern end of the bolson where it is 40 to 70% of the basin-center facies. There is no consistent texture or pattern of textural variation in the mudstone, siltstone, and sandstone units. They range from massive, slightly sandy, poorly sorted mudstone to thin-bedded interbeds of moderately well-sorted silt, mud, and fine sand. The siltstone most commonly displays horizontal laminae and ripple cross laminae, but structureless beds are present. Mudstone and siltstone beds range from a few inches to nearly 15 feet thick; many of the more massive beds are texturally complex, containing thin, irregular interbeds of claystone, mudstone, and siltstone, whereas some are structureless orange-brown mudstone. The lateral continuity of individual beds is highly variable; some can be traced only a few feet whereas others can be followed for several hundred yards.

The interbedded sandstone of the mudstone-sandstone lithosome is lighter colored, generally tan to buff, than the mudstone. Sandstone beds are 1 in to 4 ft thick and are distinct because they are more resistant to erosion than the mudstone. Most beds, as with the mudstone and siltstone, are a few inches to a foot or two thick. Near the boundary between this lithosome and the basin-margin facies, sandstone is medium to coarse, granular, and muddy; however, toward the basin center it is fine and moderately well sorted. The beds are commonly broad lenses with horizontal laminae, trough and foreset cross-stratification, and ripples. The stratification types and sequences of types indicate small-scale braids with shallow channelfills and thin barlike units in the sandstone and much of the siltstone, interbedded with the more blanket-like structureless or laminated mudstones. The pattern is similar to that in deposits at the nearly flat toes of modern alluvial fans where they merge with mud-floored playas or barrials.

Gypsum is common in the mudstone as disseminated crystals, thin beds and lenses of crystals, and as veins. Gypsum also cements some of the sandstone beds, although others are carbonate cemented and many are friable. Calcium carbonate is present in some of the mudstone and sandstone as irregular nodules. The occurrence of gypsum and calcium carbonate is discussed in detail in separate following sections.

Northern Sections

In the southern two-thirds of the bolson the mudstone-sandstone lithosome is a poorly developed, comparatively imprecise map unit. In the northern third of the bolson, however, the lithosome is well developed and makes up the best exposures in the bolson fill.

In the northeastern part of the bolson, from near Pinto Creek northward to the vicinity of Sandiguela Creek, the outcrop chracteristic of the interbedded mudstone and sandstone changes. In other areas, pediments and terraces developed on the poorly indurated mudstone and sandstone dominate the landscape, and bolson fill is exposed only in valley walls. In the northern part of the bolson, cementation of the siltstone and sandstone is more complete and a bench and slope topography is developed. The cementation and resulting more delicate differential weathering have emphasized stratigraphic detail and show that sandstone, siltstone, and mudstone are complexly interbedded and contain ripple cross laminae and horizontal laminae. Whether the pattern of textural variation and structures is a unique characteristic of this area or whether it is present in other parts of the mudstone-sandstone lithosome, but obscured by weathering and lack of cementation, is not known.

Horizontal laminae and small-scale ripple cross laminae are common throughout this area. The laminae are delicate and relatively persistent. Except for a few very thin granular medium and coarse sand lenses, the sand is fine and moderately well to well sorted; siltstones are similarly well sorted. Mudstone is present, but commonly the textural end members, silt and clay, have been deposited as distinct beds and laminae. These textural properties and sedimentary structures indicate that most of the sediments in this well-cemented part of the mudstone-sandstone lithosome were deposited from suspension in standing water and by gentle currents.

Two lithologic types not found elsewhere in the bolson are present in this area—beds of white, massive chalcedony 10 to 18 in thick and very light gray, laminated, sandy limestone. Many seeps in the area are presently depositing calcareous and siliceous material on rock surfaces. The springs coincide (1) with the zone of interfingering of the basin-margin facies with rocks of the mudstone-sandstone lithosome and (2) with a series of faults. Thus, it is difficult to determine if the chalcedony and limestone were deposited as part of the original sequence or formed as a secondary mineralization. If the mineralized ground water was not introduced along post-depositional faults, then the water was present in the subsurface or at the surface during deposition of the mud and sand; if post-depositional faulting brought mineralized water to the area, the interbeds and cement of siliceous and calcareous material are epigenetic. The intricate and fine horizontal laminations in the mudstone and algaelike strands in the limestone suggest that a body of water was probably present; groundwater discharge is a possible mechanism for maintaining it. The dominance of calcareous material and the presence of floating sand grains in many of the limestone beds further suggest that the carbonate is primary. Thus, this area may have contained a permanent or semipermanent shallow lake located at the margin of the broad basin floor; if spring-fed, this lake could have existed at the same time that another part of the basin was occupied by ephemeral or playa lakes.

Near the northern margin of the bolson, in Texas and in Mexico, sandstone and siltstone are more abundant than mudstone; broad, shallow sand and silt-filled channels covered by more extensive mudstone units are characteristic. This sandy portion of the basin-margin facies is well exposed in the bluffs along both sides of the Rio Grande north of Hot Springs Creek. Sandiness increases to the north, and conglomerate of the basin-margin facies borders much of the bolson in Mexico, where gravel-producing limestone and sandstone crop out in the bordering mountains. The northern margin of the bolson in Texas is bordered by less resistant tuffaceous volcanic rocks, and sandstone, with some interbedded conglomerate, persists nearly to the basin edge.

The abundance of sand and silt in the northern part of the bolson may reflect a major influx of sediments from the broad areas of weak Tertiary tuff and tuffaceous sedimentary rocks that crop out over much of the Rim Rock Country north of the bolson. There is no evidence that an ancestral stream of the size and extent of the modern Rio Grande entered the bolson in this northern area. Channel gravels and clasts of rock types derived from areas beyond the bordering mountains are present only in deposits that can be definitely related to the more recent excavational phase of bolson history. It is possible, however, that a relatively large drainage system, heading in the Rim Rock Country, introduced much of the mudstone and sandstone in this northern area. Directional features in the bolson fill are not consistent but do indicate a generally south, southeast, and southwest direction of transport.

In this northern area and in other parts of the bolson, sandstone beds decrease in number and thickness toward the basin center. The sand becomes finer until, over large area, siltstone is the coarsest material present in the fill.

Mudstone Lithosome

The mudstone lithosome includes all bolson-fill sedimentary rock that contains less than 10% sandstone plus conglomerate; it crops out basinward of and is gradational to the mudstone and sandstone lithosome. The mudstone, claystone, and siltstone of this lithosome are moderately well exposed in steep banks along streams and poorly exposed beneath the gravel lag covering low, rounded hills near the bolson axis.

All textural variations and combinations of clay and silt, including sandy mud, were grouped together as mudstone in designating the lithosome. Most sediment in the mudstone lithosome is texturally a mudstone as Folk (1964:27) used the term, but much is siltstone and some is claystone. These textural types are all interbedded throughout the section along with minor amounts of fine to very fine sandstone.

From a distance, outcrops of mudstone display an overall brown to orange-brown color with banding of various shades of these colors and, in places, green. These bands reflect bedding or textural variations that commonly become less distinct closeup. Green mudstone and claystone constitute a conspicuous, although volumetrically minor, part of the section. The green color bands are commonly traceable over considerable distance, nearly a mile in one area. These persistent bands seem to follow a particular bed, but it is extremely difficult to keep exact track of a particular bed over more than a few hundred feet due to intervening encrusted and covered intervals. In other places, the green coloration is mottled with brown within a unit in a "marble cake" fashion or is present as lenses.

Beds range in thickness from less than 1 in to nearly 5 ft. The more massive beds are generally mudstone that varies in texture and lacks sedimentary structures. Claystone and siltstone beds are most commonly 1 in to 3 ft thick. These rocks, especially the siltstone, display the most distinctive colors; most siltstone is tan or buff whereas the claystone is medium brown or "chocolate brown." The various shadings of brown, orange brown, and pink are most characteristic of the mudstone beds. Lateral persistence of individual beds is highly variable, but in general it ranges from a few to a few hundred feet.

Ostracods, the only fossil material collected from the bolson fill, were found in green mudstone. The valves are of the plain, unornamented "jellybean" type. Positive identification was not made, but P. U. Rodda (personal communication, 1968) suggested that they resemble modern species that are very common in standing-water bodies ranging in size from puddles to lakes.

Gypsum occurs throughout the basin-center facies but is most common in the mudstone lithosome. It occurs in several forms or modes and is discussed in a separate section. Calcium carbonate nodules and powder, similar to that in the mudstone-sandstone lithosome, are present in some mudstone and sandy mudstone beds.

Sedimentary Structures

Sedimentary structures are common in rocks of the basin-center facies; however, they are not easily discerned in all exposures. Horizontal laminae are most common in mudstone, siltstone, and fine sandstone; ripple cross laminations are present in much siltstone and fine sandstone. The scale of these structures is small; laminae range in thickness from less than 1 mm to 5 mm and ripple cross laminae are most commonly less than 1 in thick. Where interbedded mudstone and siltstone comprise the section, as throughout most of the basin-center facies, the mudstone are either structureless or laminated and the siltstones contain horizontal laminae and ripple cross laminae.

In the northern portion of the basin-center facies where fine to medium sandstone dominates the section, the generally larger scale structures include trough cross-stratification and foreset cross-stratification as well as horizontal laminae. Good exposures of these occur along the lowermost reaches of Sandiguela Creek in Texas and in the high vertical bluffs just across the river in Mexico. Troughs range from 2 to 6 in in depth and are from 1 to 2.5 ft wide. Braided channel sequences are indicated by trough cross-stratification and by foreset cross-stratification associated with channel bars. Foreset cross strata, present in medium sandstone, dip gently and are up to 8 in thick. Horizontal laminae are 1 mm to 1 in thick and consist of interlaminated silt and fine sand. Ripple cross strata up to 1½ in thick are present in the muddy siltstone. Mudstone beds comprise up to 25% of the section at the Sandiguela Creek locality; they are 2 to 18 in thick, commonly delicately laminated, and can be traced up to 60 feet along the outcrop. Deformed or convolute bedding is present in slump sections up to 3 ft thick; smaller scale deformation of laminae is common throughout the basin-center facies wherever mud and silt or sand are interbedded.

Thick sequences of mudstone contain beds up to 3 to 4 ft thick that are structureless as well as thinner beds that are commonly very delicately laminated on a small scale. The structureless mudstone is generally brown to red brown whereas many of the finely laminated beds are very clayey and greenish. Laminated and rippled siltstone beds are present in some of these sequences.

The delicate, small-scale ripples and laminae in the finer grained parts of the basin-center facies reflect "gentle" currents and deposition from suspension. As silt and sand beds increase in number, ripples, troughs, and foresets become more common and the scale increases; interbedded mudstone shows little change in scale or types of structures. This pattern is established laterally from the thick mudstone sequences near the basin center through increasing sand content toward the basin margin. This change in type of structures and scale reflects the change from deposition in standing water by currents and suspension, to deposition by small-scale braided streams near the water-body margins and on the toes of alluvial fans. The interbedding of mud with silt and sand is a result of fluctuation in the loci of these types and sites of deposition. The patterns of sedimentary structures reinforce and supplement the lithologic data upon which the interpretation of the basin-center depositional environment is made.

Gypsum

Gypsum is common in the basin-center deposits; it is present in mudstone, siltstone, and fine sandstone as:

1. Disseminated crystals and subhedral grains;

most are small (0.5 to 3.5 mm), but larger (to 10 cm) clear selenite crystals are also present.

2. Lenses and thin (1- to 8-in beds) of subhedral crystals in a clay and mud matrix. The amount of matrix ranges from 10 to 50%.

3. Distinct beds and large lenses of fine-grained, massive, white, pure gypsum and translucent, honey-colored gypsum. Beds and lenses are ½ in to 2 ft thick.

4. One-fourth to 1 in-wide veins.

5. Cement in moderately to well-sorted, relatively mud-free sandstone.

Gypsum occurs most commonly as disseminated crystals and, in some places, beds and pods of crystals. It is most common in mudstone; most mudstone that contains gypsum is brown or orange brown, but it is not uncommon to find gypsum associated with green or yellow mudstone. Mudstones containing gypsum typically lack sedimentary structures and vary texturally within a given bed from claystone to sandy mudstone; some of this textural heterogeneity and lack of structures may be due to disturbance of the sediment as the gypsum crystals grew. Gypsum crystals are concentrated in some interbedded mudstone and sandstone sequences into pods, lenses, and beds ½ in to 8 in thick. The crystals are randomly oriented in a brown or green mud matrix.

Bedded, massive gypsum was observed at only one locality. The claystone and mudstone with interbedded gypsum are faulted out basinward of this outcrop making it impossible to determine the geometry of the gypsum deposit beyond the 200 yd of continuous exposure at this locality. The massive gypsum here is clear and colorless to snow white and finely crystalline. This thick (2½ ft) bed of gypsum grades eastward, toward the mountains, into finely interlaminated gypsum and clay; rocks of this type are present in the mudstone lithosome from this area north to at least Pinto Creek. The thin-bedded gypsum that is interbedded with laminated green and orange claystone is fibrous in some places, honey-colored and translucent in others. The bedded gypsum is in the mudstone lithosome and is overlain and underlain by brown and orange-brown mudstone typical of this lithosome. The total amount and lateral extent of gypsum exposed at this locality are not impressive, but they do indicate that ponded, highly mineralized water was present, in at least this part of the bolson, during the deposition of part of the basin-center facies.

Veins of translucent, honey-colored gypsum are common throughout the mudstone lithosome and basinward parts of the mudstone-sandstone lithosome. Some veins are clearly filled fractures associated with faults; others may be filled desiccation cracks similar to those developed in playa muds in bolsons in the Mojave Desert of California.

Gypsum-cemented sandstone is moderately common in the basinward margins of the mudstone-sandstone lithosome. These sandstones are moderately well sorted and mud-free. Veins of gypsum are commonly associated with the mudstone-sandstone sequences and the mudstones contain gypsum crystals. Some sandstone contains pods of crystalline gypsum that are probably filled voids or vugs.

Gypsum occurs in Mojave Desert playa sequences in the same forms as in the Presidio Bolson (Thompson 1929; Bassett and others 1959). Associated sediments are also similar, both in type and distribution, suggesting that the Presidio Bolson clastics and gypsum accumulated in environments similar to those in which Mojave Desert playa and permanent lake deposits were deposited during the Pleistocene and Holocene.

Calcium Carbonate

Irregular, knobby, white to light gray calcium carbonate nodules are present in sandstone, sandy mudstone, and pebbly sandstone at various places in the bolson fill. Most are an inch or less long and ¼ to ½ in in diameter; irregular nodules of this type are common in siltstone north of Burro Creek in the Redford Bolson. The slopes below the siltstone are littered with nodules. They are accompanied in some places by streaks of powdery carbonate material. Similar nodules occur in sidestream-fill deposits which are associated with dissection of the bolson fill by the Rio Grande and its tributaries. These nodules strongly resemble ones in lower alluvial-fan and playa-margin deposits in the Mojave Desert of California and in terrace and pediment deposits in the Mesilla Bolson in southern New Mexico. Hawley and Gile (1966:28-29) have described the carbonate nodules in the Mesilla Bolson; they have clearly demonstrated that the carbonate nodules are a step in the sequence of caliche development in nongravelly materials.

Tubelike calcite forms a delicate network in muddy sandstone in parts of the fill in the Redford Bolson along the large sidestream south of Auras Creek. The tubes are commonly less than 3 mm in diameter; they stand out clearly on weathered surfaces. They do not resemble pedologic carbonate and may be roots and other parts of plants. Longer pieces of sticklike carbonate, ½ in in diameter and up to 3 in long, with a woody surface texture, are present with the smaller tubes. Similar material from the Santa Fe Group in southern New Mexico has been described by LeMone and Johnson (1969:85, 87) as the stems of succulent (?) plants.

The extensive tufa and limestone deposits in the northeastern part of the bolson fill have been described in a previous section.

Environment of Deposition

Rocks of the basin-center facies were deposited at the toes of alluvial fans that extended toward the basin center from the surrounding mountains, in ephemeral playa lakes, and in more permanent lakes that contained water for long periods of time. This interpretation is based on the types of rocks present—their geometry, distribution, and relationships with basin-margin deposits—and on analogy to well-documented modern and ancient basin deposits. There is no question concerning the general environmental reconstruction as a basin center surrounded by alluvial fans extending from adjacent mountain blocks; this is a face of geography and physiography. The principal matter for interpretation is the conditions of deposition and the source of the sediments.

Modern desert basins in the Basin and Range Province are analogous to the Presidio Bolson in physical setting. Alluvial fans from nearby mountain blocks extend toward the basin center, interfingering there with thick sequences of mud and interbedded silt and sand that underlie dry lakes or playas. Many modern basins were the sites of permanent lakes during Pleistocene pluvial periods; some were fed by extensive drainage systems originating far from the basin, others were not. The stratigraphy of several of these basins has been well detailed; some of the more enlightening works include studies of the Lake Bonneville basins by Hunt and others (1953) and Feth (1955), of the Great Salt Lake by Eardley (1938, 1966), of the Salton Sea by Arnal (1961), and of Lake Lahontan by Morrison (1964). Core logs from several basins in the Mojave Desert (U.S. Geological Survey, 1960) and playa studies at the University of Massachusetts (Motts and Carpenter 1968) have also contributed to the understanding of desert-basin sedimentation and stratigraphy. Deposits elsewhere in the Rio Grande depression similar to these and to the Presidio Bolson fill have been described by Wright (1964) for the Rio Puerco area, by Strain (1964) for the Hueco Bolson, and by others. The similarity of Presidio Bolson basin-center deposits to those described from similar basins is pronounced and predictable.

Much mud and sand in modern desert basins were deposited at the toes of alluvial fans and near the margins of ephemeral playa lakes. The small-scale foresets and troughs in sandstone beds, and the filling of local lows by muds, are characteristic of the shallow-braid channels and local depressions present near the toes of modern alluvial fans and on the adjacent desert flats. The fluctuation of this zone, as the locus of playa deposition shifted, is represented in the mudstone and sandstone lithosome by thicker, more persistent brown, generally structureless, mudstone beds representing playa-lake deposits. Much or most of the mudstone-sandstone lithosome was deposited on the nearly flat toes of alluvial fans adjacent to playa and more permanent lakes. This is further indicated by the caliche carbonate nodules found in modern basin deposits in the toes of fans and in the mudstone-sandstone lithosome of the Presidio Bolson fill.

The mudstone lithosome, characterized by brown structureless muds interbedded with laminated siltstone, mottled brown and green clay, and delicately laminated claystone, is made up of sediments deposited in lakes of varying permanence. Most common are the broad lenses of brown mud characteristic of modern playa-lake deposition. The laminated or varied silts and green mudstones are similar to those deposited in permanent lakes as described from Pleistocene Lake Bonneville (Alpine Formation) by Feth (1955), from Lake Manix in the Mojave Desert by Blackwelder and Ellsworth (1936), and from the Green River Formation by Bradley (1964). The interbedded laminated silts, clays, and algal limestones in the Ruidosa Springs area are clearly lacustrine, perhaps deposited in a localized water body maintained by springs issuing from the fault zone as they do today. The intertonguing of the permanent-lake-type deposits with playalike mudstones and the interfingering of all the basin-center sequences with alluvial-fan deposits indicate not only that the type of lake varied but also that the locus of deposition of fine-grained sediments was not static.

The common occurrence of gypsum indicates a hydrologically closed basin during at least some stage of deposition, but the lack of great thicknesses of evaporites argues against a persistent end-of-the-drainage-line type of lake maintained in a highly saline condition with alternate freshenings. In fact, the dominance of playa-lake-type deposits suggests that the bolson was the site of a dry lake throughout much of its history, perhaps with a more permanent spring-fed body of water existing in the Ruidosa area.

It is not clear whether or not a drainage system of large regional extent ever terminated in the Presidio Bolson. Physical barriers, such as the mountain blocks surrounding the basin, limit the access of an aggrading stream from several areas. If a larger stream did feed the Presidio Bolson, the most likely entry point would be near the north end of the basin where the Rio Grande presently enters the bolson. The abundance of sandstone in the fill at this end of the basin may be an indication of a major sediment source in that area. The extent of any such stream beyond the Rim Rock Country cannot be inferred because deposits are not preserved that might provide evidence. Gravels at the north end of the basin do not contain clasts that require a distant source.

In the Hueco Bolson (Strain 1964) and in the Red Light Bolson (Akerston 1967), the finer grained basin-center deposits are mantled by basin-margin-like gravels interpreted by these workers as the response to integration of basin drainage by a through-flowing regional stream as described by Wright (1946:399). Unless the Rio Grande gravels that underlay the surface mapped at Qg4 by Dickerson (1966) and Haenggi (1966) represent the first entry of a regional mainstream into the basin, this encroachment of coarse detritus over basin-center deposits is not present or not preserved. If this "Ruidosa Conglomerate" of Dickerson (1966) is the earliest axial mainstream gravel deposit, then the associated pediment gravel represents the sidestreams' response to drainage integration. Unfortunately, the evidence is inconclusive.

Age

The analogy of the Presidio Bolson fill to the Santa Fe Formation in the Rio Grande depression in New Mexico (Wright 1946; Hawley and others 1969) and to deposits described by Strain in 1964 (Fort Hancock Formation) and Albritton and Smith in 1965 (older basin deposits) in the Hueco Bolson, is strict in terms of genesis and probably they are in part equivalent in age. Strain (1964:50) concluded that his Hudspeth local fauna, derived in part from the upper playa deposits that constitute the Fort Hancock Formation, probably lived during the Aftonian Age of the Pleistocene. The Santa Fe Formation has long been considered late Miocene and Pliocene on the basis of vertebrate fossils (Denny 1940:94); Wright (1946:413) found vertebrate remains that indicated a late Tertiary age for the Santa Fe in the Rio Puerco area. Thus, the bolson fills in the bolsons along the Rio Grande in New Mexico and Texas were deposited in basins formed by middle Tertiary (Miocene ?) faulting; the ages of the deposits, from Miocene through early Pleistocene, indicate the general period of filling. Because no evidence was found in the Presidio Bolson for dating the deposits, it can only be stated with certainty that the bolson fill is post-middle Tertiary block-faulting and probably approximately the same age as the fills in other bolsons along the Rio Grande.

APPENDIX 5

EXCAVATION PHASE DEPOSITS IN THE PRESIDIO AND REDFORD BOLSONS
(from Groat 1973:26-32)

MAINSTREAM

Modern Rio Grande

Deposits of the modern axial mainstream, the Rio Grande, consist of channel gravels and floodplain sand, silt, and mud; floodplain deposits are exposed over a much larger area than are the channel gravels. Together these deposits constitute the channel-floodplain complex.

Channel deposits of the modern Rio Grande are exposed in the active channel and on bars located downstream from the juncture of Alamito Creek. Rio Grande gravel ranges in modal size from granules to large cobbles. The gravel is moderately well sorted, sandy, and most clasts are moderately well to well rounded. This rounded characteristic of Rio Grande gravel is distinctive; sidestream gravels are mostly angular to subangular with a few moderately rounded clasts.

Another distinctive property of the mainstream gravel is its lithology. Several pebble counts made on bars and on mainstream terraces standing adjacent to the modern Rio Grande demonstrate a persistent quartzite-limestone-volcanic rock assemblage. The influence of local contributions by nearby sidestreams is apparent, but the persistence of the well-rounded quartzite-limestone-volcanic rock suite throughout the length of the Rio Grande in this basin is striking.

Mainstream gravels also contain clasts foreign to the mountains enclosing the Presidio Bolson. The most distinctive of these is a sandy chert-pebble conglomerate drived from the Las Vigas or Yucca Formation which crops out north of most of the Presidio Bolson. These clasts are easily recognized and are present only in mainstream or reworked mainstream gravels. These "foreign" clasts, the quartzite-limestone-volcanic rock suite, and the well-rounded clasts give mainstream gravels an aspect distinctly different from the more angular sidestream gravels characterized by clasts that can be traced directly to outcrops in the headwater areas of each stream.

The other mainstream in the area, the Rio Conchos, drains a vast area in Mexico ranging from the sedimentary rock terrain of most ranges in the Mexican Highlands section of the Basin and Range Province, to the volcanic highland of the Sierra Madre Occidental. The lithology of Rio Conchos gravel in the bolson area reflects chiefly the limestone and sandstone outcrop areas, although a few volcanic-rock clasts are present.

Rio Grande floodplain deposits were not studied in detail. Observations were made in shallow cuts in cultivated areas and on terraces where sidestream influences were not great. Floodplain fine and medium sand, silt, and mud are generally 1 or 2 ft to as much as 5 ft thick. Fine sand with small-scale (1 to 4 in thick) trough cross-stratification overlain by a thin layer of rippled and horizontally laminated mud is common; however, details of the sedimentary structures have been destroyed by roots in many places. Thin stringers of gravel, both mainstream and sidestream, are present.

The map relations of the mainstream channel-floodplain complex to sidestream and bolson-fill deposits are shown by Groat (1972:Plate 1). The modern floodplain extends laterally toward areas influenced by sidestreams, where it abuts against low scarps cut by meander swinging or merges with sidestream-fan deposits which are interbedded with and built out over the Rio Grande floodplain deposits. The cross-sectional relationships are best displayed in older, higher deposits that have been dissected.

Older Mainstream

Older mainstream gravels resemble modern Rio Grande gravel in lithology, roundness, and the presence of "foreign" clasts. As with modern Rio Grande gravel, the well-rounded quartzite-limestone-volcanic rock suite is persistent and distinct. These gravels were deposited by a large through-flowing mainstream similar and ancestral to the modern Rio Grande.

Gravels deposited by the ancestral mainstream are exposed in many places in the axial area of the bolson. They occur at various heights above the modern Rio Grande on terraces and in erosional remnants capped by sidestream pediment and terrace gravels. Mainstream gravels are well preserved in the toes of pediments on both sides of the Rio Grande north of Ruidosa. Many low sidestream terraces and pediment remnants between Ruidosa and Alamito Creek are developed on Rio Grande deposits; not all these were mapped individually, but the lateral extent of mainstream gravels throughout the bolson was determined. Mainstream terraces, with little or no alteration by sidestream activity, are preserved from south of Ojinaga north to Cerro Alto in Mexico.

The mode of occurrence of the older mainstream gravel is similar in all areas. Channel gravels are 6 to 12 ft thick; thicker mainstream deposits are not common. Near the end of the pavement west of Farm Road 170, adjacent to the Rio Grande, 30 ft or more of mainstream gravel crops out in a steep bluff. The construction of the Rio Grande is pronounced in this area, probably because sidestreams enter the valley here. The gravel was thus stacked in a narrow band as the river cut down with limited lateral movement.

The gravel is sandy (medium to very coarse sand) and moderately to moderately-well sorted. Most is medium-pebble to medium-cobble gravel, overlain in a few places by mud and fine sand interpreted as floodplain deposits but in most places by sidestream gravel. Stratification of the channel gravel is not well defined; crude parallel beds and trough cross-stratification are recognizable at some places.

The mainstream gravels are in erosional contact with underlying bolson fill at all places the contact was observed; at no locality does bolson fill overlie mainstream gravel. In most places older mainstream gravel is overlain by 5 to 25 ft of sidestream sand and gravel. These relationships can be observed at many localities along the basin axis, for example, near Fort Leaton 3 miles southeast of Presidio, in many stream cuts between Adobes and the Zimmerly Experimental Farm, and along the bluffs on both sides of the Rio Grande near Ruidosa. Older mainstream gravel without significant sidestream-gravel caps is present on the Mexican side of the Rio Grande from Ojinaga north to Cerro Alto. These terraces lack a sidestream gravel mantle only because there are no gravel-producing mountain blocks near enough to the river area to supply the detritus.

Mainstream deposits were spread laterally as the ancestral Rio Grande swung across the valley floor. As it moved away from one side of the valley toward the other, the sidestreams on the recently occupied side of the valley spread sand and gravel over the mainstream deposits as fans of varying thickness.

SIDESTREAMS

Modern Deposits

Ephemeral streams transport detritus eroded from the bolson deposits and from the surrounding mountains toward the Rio Grande. Over most of the bolson these streams are eroding by lateral and vertical cutting. During the process of removing the bolson fill the streams leave a sandy gravel veneer over the beveled bolson fill: (1) in distinct channels of varying width in areas where one or a few vigorous streams dominate the drainage system, as along Alamito, Cibolo, and Hot Springs Creeks; some of these channels broaden into fan-shaped surfaces near the Rio Grande where lateral corrosion by the sidestream is most pronounced; or (2) as a broad, thin surficial mantle where many small streams have carved an irregular broad surface of low relief, such as the broad plain east of Ochoa and northeast of Adobes. These sidestream deposits are absent in the upper and middle reaches of many streams, where bolson fill is exposed in the wash floors, and at least 8 ft thick near the Rio Grande where streams are slightly incised into sidestream alluvium. Bolson fill is not exposed in stream bottoms near the basin center.

Several large sidestreams are eroding bolson fill along their upper and middle reaches while building alluvial fans out onto the valley floor near the Rio Grande; Pinto and San Antonio Creeks are good examples of sidestreams that are definitely aggradational in their lower reaches. The thickness of these fan deposits is unknown; relief between fan surfaces and the surfaces the fans are built onto suggests at least 30 ft of sidestream alluvium. Several triggering mechanisms and causes for fan deposition are possible, but most common either capture or swinging away of the Rio Grande is responsible.

The composition and texture of sidestream deposits are extremely variable; they are influenced strongly by the lithology of the bedrock and/or bolson deposits drained by each stream. Streams draining resistant limestone, sandstone, or lava outcrops transport much gravel. The lithology of these gravels, as determined by pebble counts, reflects the rock type exposed in the headwaters areas. Streams draining West Chinati Peak, a syenite intrusive body, transport much sand but very little gravel. Sidestreams heading in the tuffaceous volcanic rocks east of Ochoa likewise transport little gravel but much mud and sand; gravel-size clasts are not produced during weathering of the tuffaceous rocks or of the syenite. Many sidestreams crossing mudstone and claystone of the bolson fill carry armored mudballs.

The thinnest, least gravelly sidestream deposits are those deposited by the numerous smaller sidestreams that head in the bolson fill, especially those originating in the basin-center facies. Much of the beveled bolson fill in Texas from Pinto Creek to south of Ochoa is mantled by thin, sandy alluvium spread by the numerous small streams that head in the fine bolson-center rocks that dominate the area. Some streams are reworking older pediment and terrace deposits and thus carry some gravel, but the amounts are small. The valley border surface, the area between the edge of the Rio Grande floodplain and the ends of the pediment spurs, is strewn with reworked pediment gravel and bolson-fill deposits laid down by these abundant smaller, local streams, some of which carry sediment out onto the Rio Grande floodplain.

Pediment and Terrace Deposits

Pediment and terrace remnants stand at various heights above modern stream channels. The deposits mantling these surfaces were left by the streams that cut the surfaces, streams analogous in morphology and source areas to modern sidestreams but which were graded to higher elevation of the Rio Grande during earlier phases of excavation of the bolson fill. The origin and history of development of these surfaces have been discussed in detail elsewhere (Groat 1970a, b).

Old terrace and pediment deposits are chiefly sandy gravel, for only surfaces mantled by gravel are resistant to erosion and therefore preserved; erosional remnants capped by sidestream deposits are scarce in areas where the sidestreams head in nongravel-producing bedrock or within the bolson. The coarsest, most gravelly pediment and terrace deposits are those that cap the prominent erosion surfaces adjacent to the major sidestreams, such as Alamito, Cibolo, and Hot Springs Creeks. The lithology of gravel clasts in these older sidestream deposits is similar to that in adjacent modern streams and reflects bedrock lithology in the adjacent mountains.

The thickness of the older terrace and pediment deposits is variable and bears no consistent relation to the height or age of the surface beneath the deposits. In most places terrace and pediment gravels are 5 to 15 ft thick, but as much as 40 ft is present in some areas. In some places the deposits are thickest near the mountains and thin toward the basin axis; in others there is an appreciable increase in thickness toward the basin center. Thick deposits, up to 50 ft, near the mountains probably represent local fan and slope-wash deposits. They are poorly sorted, locally derived, and "bedding" is inclined at angles that approximate the slope of the land surface at the base of the mountains. The increase in thickness of some terrace and pediment deposits toward the basin center reflects transition from channel gravels deposited as sidestreams eroded the bolson fill, to fans these streams built onto the valley floor, and to valley fills. The preserved thickness of older sidestream deposits near the basin center is largely a function of how far the Rio Grande has swung laterally, that is, whether all, part, or none of the thicker sidestream-fan deposits, if ever present, have been removed by the mainstream.

The older sidestream terrace and pediment deposits are coarser than the bolson fill they overlie. Where sidestreams have built fans onto the valley floor there is more sand and mud than in the middle and upper reaches of the streams, but in terrace and pediment deposits the sandy gravel present in the upstream reaches is also present near the basin center. In the upstream reaches, the sidestream gravel is coarser than the bolson conglomerate it overlies there. This textural contrast between bolson deposits, which grade from conglomerate near the basin margin to mudstone near the basin center, and overlying sidestream deposits, which are sandy and gravelly from basin margin to center, is due to a fundamental genetic difference in the origin of the two kinds of deposits. The bolson fill was deposited in a closed basin by upgraded aggrading streams; these streams dumped the coarsest part of their load near the basin margin and carried only the finer sand and mud to the basin center. When the Presidio Bolson became integrated with other basins by a through-flowing axial mainstream and excavation of the bolson fill began, debris carried toward the basin center by sidestreams was transported out of the basin by the mainstream. The sidestreams became graded to the mainstream and all of their load, including gravel and sand, reached the basin center; channel deposits left on erosional surfaces by these streams reflect this difference.

Caliche

Caliche is present in many higher and older terrace and pediment deposits capping the pediment remnants adjacent to or near the major sidestream. Although the completeness of cementation of the gravels is variable, and is generally less complete on lower, younger surfaces, the sequence on each is similar: (1) the surface is armored with a one-pebble-thick armor, commonly varnished; (2) beneath the pebble layer are 1 to 3 inches of "honeycombed" or porous, slightly indurated silt and mud with patches of white calcium carbonate powder or crusts; then (3) 6 in to 2 ft of light brown or buff silt with scattered pebbles or cobbles and containing disseminated white powdery, calcium carbonate; some of the gravel clasts are commonly partially coated with a white calcium carbonate crust that increases with depth; and, finally, (4) gravel that is partially or completely cemented by white calcium carbonate. The chief differences noted in several trenches dug in the highest to lowest surfaces near Cibolo Creek was in the degree of cementation of unit 4. Little or no difference was noted between the profiles on Dietrich's (1965) high Qg2 and slightly lower Qg3, but the gravels of the lowest or Qg4 surface are not cemented. These lower terrace deposits throughout the bolson lack the caliche cement common in the higher deposits.

Caliche development on the highest extensive surfaces has the complete sequence described above. The degree of caliche development on these surfaces does not approach the massive, complex profile of the high La Mesa surface described in an excellent account by Hawley and Gile (1966) of caliche formation on valley-border surfaces. Whether or not this is due to a younger age for the high surfaces in the Presidio Bolson is unknown.

Sidestream Fills

Relatively thick deposits of sidestream gravel and sand are exposed in the basinward edges of pediment remnants adjacent to several of the large sidestreams. These sediments were deposited in the zone of interplay between the mainstream valley and the mouths of sidestreams on alluvial fans and in ponds on the mainstream floodplain. The details of the relationships between sidestream and mainstream deposits are commonly complex. Thick sidestream fills occur near the mouths of Alamito, Cibolo, and Sandiguela Creeks; only the Sandiguela fill complex is described here.

Sandiguela Creek

The most interesting, probably because it is the best exposed, sidestream-fill sequence crops out along the lower reach of Sandiguela Creek in the northern part of the bolson. The sequence postdates, by an unknown period of time, the formation of the Qg4 surface and the Rio Grande gravel ("Ruidosa Conglomerate") beneath this surface as mapped by Dickerson (1966).

At the eastern apex of the valley fill, the sediments are gravel and sand that were deposited in channels cut into the bolson-fill sandstone and mudstone. Toward the Rio Grande the gravel and sand are interbedded with volcanic ash and both of these are interbedded with thin-bedded sandstone and mudstone that contain nonmarine ostracods, reported by Dickerson (1966:27) as *Deyogypris* sp., *Candona angulata* G. W. Muehller, and *Cypria* sp. (?). Terrace gravel caps the 20 to 35 ft of fill exposed along Sandiguela Creek. At the southern edge of the sequence, the ash directly overlies Rio Grande terrace deposits that are a few feet lower than the mainstream gravels underlying the Qg4 surface.

The thin-bedded, and in places laminated, muds and fine sands and the interbedded structureless ash were probably deposited in shallow, ponded water along the valley border fed by Sandiguela Creek or the Rio Grande. The clean ash is probably of air-fall origin, the fine sediment could be of either Sandiguela Creek or Rio Grande origin, and the gravel was deposited by Sandiguela Creek.

Strain (1964) reported volcanic ash from his Camp Rice Formation, which he believed is an aggradational unit deposited on the mainstream valley floor in the Hueco Bolson; he correlated the ash with the Pearlette. (See additional discussion of this ash in the section on the age of the Rio Grande-Rio Conchos system presented earlier in the text by Deal.)

This fill unit is not especially thick, but the presence of the ash and its stratigraphic relationships make it an interesting one. The deposits are definitely post-bolson fill and postdate the entrenchment of the Rio Grande and the formation of the Qg4 surface of Dickerson (1966). Another ash deposit north of Spencer Creek, overlying Rio Grande gravels here, may be correlative with this deposit. If so, the relationship of some geomorphic surfaces in separate parts of the bolson can be inferred. The possible correlation of this ash with ashes in distant parts of the Rio Grande complex presents the only possibility of linking histories of the physically separated basins.

DISCUSSION

All deposits described in this section have one thing in common. They were deposited during the excavation phase of Presidio Bolson history—they postdate the initiation of a through-flowing axial mainstream. Most deposits—mainstream terrace gravels, sidestream pediment and terrace deposits, and modern alluvium—bear no unique relation to the history of excavation. They are essentially lag deposits left as erosion proceeded. The question to be considered here is, do the sidestream-fill deposits reflect special conditions such as pauses in downcutting or aggradation, or are they also the result of processes incident to excavation?

No unqualified interpretive statement regarding valley of sidestream fills is possible because they are geographically separated, and only one marker, the ash, might indicate the relation of one of these fills to deposits in other basins. It can be stated that sidestream processes active today could account for the sidestream fills in at least as suitable fashion as a period of aggradation by the mainstream, which is not documented in the Presidio Bolson. Fan building, capture, and shifts in the position of the mainstream, as described in the section on geomorphology, are all factors that are presently accumulating deposits that resemble some of the valley fills. Climatic differences during deposition of some of the fills, such as the lacustrinelike parts of the Alamito—Black Hills-Torneros and Sandiguela fills, could account for ponded water along the mainstream-valley margin. This is not to say that a general period of aggradation did not occur during the history of excavation, or that these valley fills are definitely not related to such a period; rather the point is that there is no evidence that general aggradation of the mainstream valley *must* be responsible for the separated fills. An understanding of the relationship of the valley-fill deposits of the Presidio Bolson to the Camp Rice Formation in the Hueco Bolson (Strain 1964:33) and to the "Mixed Rounded Gravels" in the Mesilla Bolson (Ruhe 1962) awaits (1) the results of studies of the ash deposits in all of these areas or (2) another type of evidence for determining correlation.

A VEGETATIONAL SURVEY OF THE COLORADO CANYON AREA

Mary Butterwick and Stuart Strong

INTRODUCTION

The valley of the Rio Grande River and the adjoining ranges and canyons of the Bofecillos Mountains represent two distinct units within the Colorado Canyon study area.

Frequently bordered by a sandy flood plain, the Rio Grande forms a narrow green belt supporting dense growths of carizzo (*Arundo donax*), seepwillow (*Baccharis glutinosa*), salt cedar (*Tamarix aphylla*), and tree tobacco (*Nicotiana glauca*). Bermuda grass (*Cynodon dactylon*), yerba del tajo (*Eclipta alba*), and salt heliotrope (*Heliotropium curassavicum*) are herbs commonly forming the lower ground cover. Above the reaches of the river, the area is reminiscent of Fresno Creek. Here too, the alluvial plains are creosote-dominated with various cacti such as Engelmann prickly pear (*Opuntia phaeacantha*), tasajillo (*Opuntia leptocaulis*), and pitaya (*Echinocereus enneacanthus*). The arid slopes feature typical shrub elements, including creosote (*Larrea tridentata*), catclaw acacia (*Acacia greggii*), resin-bush (*Viguiera stenoloba*), mesquite (*Prosopis glandulosa*), Spanish dagger (*Yucca torreyi*), guayacan (*Porlieria angustifolia*), and white ratany (*Krameria grayi*). Lechugilla (*Agave lecheguilla*) and leatherstem (*Jatropha dioica*), in addition to chino grama (*Bouteloua ramosa*), occupy a considerable percentage of the ground cover.

The numerous canyons that extend northward vary considerably in topography. Within the canyons, esperanza (*Tecoma stans*), evergreen sumac (*Rhus virens*), Mexican buckeye (*Ungnadia speciosa*), splitleaf brickellbush (*Brickellia laciniata*), poreleaf (*Porophyllum scoparium*), and bee brush (*Aloysia gratissima*) are commonly found. As the canyons open out, elements of the neighboring slopes such as leatherstem, ocotillo (*Fouquieria splendens*), creosote, lotebush (*Ziziphus obtusifolia*), Spanish dagger, mescat acacia (*Acacia constricta*), and guayacan occupy the terraces. Scattered springs throughout the canyons supply water necessary for the luxuriant stands of southwestern black willow (*Salix gooddingii*), cottonwood (*Populus arizonica*), and ash (*Fraxinus velutina*) that are frequently draped with canyon grape (*Vitis arizonica*) and poison ivy (*Rhus toxicodendron*). Cardinal flower (*Lobelia cardinalis*), *Cyperus laevigatus*, spikesedge (*Eleocharis macrostachya*), cattail (*Typha latifolia*), monkeyflower (*Mimulus glabratus*), and water cress (*Rorippa nasturtium-aquaticum*), all herbaceous species, frequent the shallow pools and streams of these springs.

METHODS

The plants of the Colorado Canyon study area were surveyed by two methods. First, the qualitative nature of the flora was determined by a collection of plant specimens throughout the major areas associated with the Rio Grande and adjoining canyons. Identifications of the species were made according to the *Manual of the Vascular Plants of Texas* (Correll & Johnston 1970) and the *Manual of the Grasses of the United States* (Hitchcock 1950). Specimens collected have been stored at the University of Texas Herbarium.

Second, the composition of the vegetation was measured quantitatively. Three areas were chosen as a sample of different environmental forms: ridge tops, igneous slopes of varying orientation to the sun, and alluvial plains. In all the sample areas the quadrat plot method was used according to the procedure described by Curtis and Cottam (1965). A 0.1-m quadrat (a rectangular metal frame) was placed along a 100-m tape at 10-m intervals. At each interval, the ground cover percentage of each plant species falling within the quadrat was recorded. The 100-m tape was then moved 10 m to the side to form a parallel line, and the procedure was repeated. Additional lines were run until no new species were found. From this data it was possible to calculate the numerical frequency of each species, ground area covered by all the plants, and relative frequency and relative dominance among the species (Appendix 2).

DISCUSSION

The Big Bend country, with its unique and unusual life forms, has attracted the attention of botanists since the middle of the 19th century. Charles Wright made extensive botanical collections throughout the Southwest between 1849 and 1852, thus becoming the first contributor to our knowledge of the vegetation of this region. Shortly afterwards, John Torrey (1858) wrote the "Botany of the Boundary" in conjunction with the United States-Mexican boundary survey. Following the turn of the century, William Bray (1905) and Mary S. Young (1914), both professors at the University of Texas, wrote descriptions of the ecology and botany of the area. A recent botanical treatment of the Big Bend area has been produced by B. H. Warnock (1970), a professor of Botany at Sul Ross University and an authority on West Texas flora.

Little botanical work has been done specifically on the Colorado Canyon study area except for incidental collections.

Climatic conditions found here reflect those typically found in a desert environment. Water is limited, with a mean annual precipitation of about 20-30 cm and an evaporation rate of about 23 cm a year, the highest in the state. Mean annual temperatures are 18°-19°C and the warm season (number of days in which temperature is above freezing) extends from 230 to 245 days out of the year. The intensity of sunlight is indicated by a mean annual possible sunshine of 70-80 % (Arbingast 1973).

The climatic conditions in the Colorado Canyon are typical of desert regions in general, resulting in a harsh environment for any form of life. In contrast to animals, the inability of plants to improve their situation by moving to a better area makes the survival of desert plants especially difficult. Consequently, the plants' survival and geographical distribution are dependent upon having characteristics that facilitate their ability to cope with demanding environmental conditions, primarily climate. The predominant plants of the desert are those that have successfully met the challenge of living in a water-scarce land. A well-known adaptation is the presence of water-storage tissue. Cacti are noted for their fleshy stems which store water and food. The agave and Spanish dagger store food and water in their leaf bases, while sotol and bear grass use their roots and woody bases for storage. Herbaceous perennials, such as umbrella-wort (*Allionia choisya*), rain-lily (*Cooperia* sp.), and angel-trumpets (*Acleisanthes longiflora*) have tuberous roots or bulbs for storage and stems which arise only under favorable conditions. Ocotillo (*Fouquieria splendens*), which stores food reserves in its woody stems, drops its small leaves during dry periods in order to retard water loss by transpiration. The presence of very small leaves among desert plants is also thought to be a method of reducing possible water-loss by transpiration through the leaves; this pattern is exemplified by the acacias (*Mimosa biuncifera*), mesquite, white ratany (*Krameria grayi*), and dalea (*Dalea formosa*). Creosote, tarbush, and resin-bush have resinous coatings on their leaves which may reduce the rate of water-loss. Similarly, the presence of leaf hairs is considered to be a device to retard water-loss; this is seen in the silver leaf and species of *Croton*. Annual plants are able to remain in dormancy as a seed until the proper conditions of moisture and temperature exist to stimulate germination; this phenomenon is seen in bladderpod (*Lesquerella fendleri*), gilia (*Gilia rigidula*), nama (*Nama hispida*), and desert baileya (*Baileya multiradiata*). Ferns and selaginella possess the ability to roll up their fronds to reduce exposure to the heat.

In contrast to the harsh conditions of the dry mountain slopes and plains, the canyons enjoy more water and protection from the desiccating winds and intense sunlight. As a result, the relatively hospitable conditions in the canyons facilitate the growth of plants that have not undergone adaptations to severe desert conditons; these plants frequently are the same ones that are normally found in more favorable climates. It is assumed that they are relics from a time when the region had a wetter climate.

The information gathered in this study indicated that four major plant associations existed in the Colorado Canyon, each corresponding to one of the major types of terrain: mountain slopes, alluvial gravel; riparian regions, and canyons. It was found that any one of these topographic areas tended to support a distinctive group of plants different in type and proportion from the others. That is not to say that within any one of the four areas there was a homogeneity of plants throughout. In fact, the combination of plants in two adjoining places frequently varied noticeably. This type of local variation in plant composition has suggested to some that each homogeneous local association of plants comprises a separate association. Our data suggested otherwise. Although local variations did occur, there was a persistent ubiquity of some species. The local variations that did occur within a single type of terrain were reasonably attributable to the random ebb and flow of plants over time. It is probable that each of the four major terrain types is capable of supporting many changing combinations of its favored plants. Since the data was consistent with this assumption, a conclusion of this report was that the major plant associations were dependent upon and generally contiguous with the four major types of terrain to be discussed below. It must be pointed out that plants characteristic of one of the four regions were not necessarily found there exclusively, but they were notably more likely to be there than elsewhere. The exception to this rule was a group of plants that was ubiquitous throughout the Colorado Canyon. Among them were resin-bush, creosote, mesquite, bee brush, and prickly-pear. Their presence constituted a point of overlap between the associations.

THE SLOPE ASSOCIATION

The slope association is basically a continuation of that found in the Fresno Creek study area. Catclaw acacia, mescat acacia, Spanish dagger, ocotillo, mesquite, resin bush, guayacan, and allthorn (*Koeberlinia spinosa*) are common shrubs. A noticeable absence of sotol (*Dasylirion texanum*) throughout the Colorado Canyon area is apparently a response to lower elevations. Sotol is a prominent feature of the rim of the Solitario and higher slopes of Fresno Creek.

The relative abundance of lechuguilla and leatherstem, possibly as a result of grazing and aridity, is a distinctive feature of these slopes. A quadrat transect on an igneous slope of Santana Mesa (see map) showed lechuguilla to be first in dominance, accounting for 24.59% of the total coverage while leatherstem accounted for 9.68% (Table 1, Fig. 1).

Chino grama (*Bouteloua ramosa*) is the most frequently encountered grass. North-facing slopes in the vicinity of Closed Canyon remain relatively undisturbed because insufficient water has discouraged grazing. It is here that chino grass makes up 33.7% of the total coverage (Table 2, Fig. 2). Mesa muhly (*Muhlenbergia monticola*), Wright three-awn (*Aristida wrightii*), common curlymesquite (*Hilaria belangeri*), needle grass (*Stipa eminens*), and fluffgrass (*Erioneuron pulchellum*) are minor components. *Machaeranthera gypsophila* is locally abundant at the Closed Canyon transect site but is very limited in the distribution and thus cannot be considered as characteristic of the slope association. Another interesting plant collected from this site is slimlobe globe-berry (*Ibervillea tenuisecta*), a rather slender inconspicuous vine with leaves that are five-parted into linear lobes. It is much more distinctive when its bright-red globose fruits are present.

As with Fresno Creek, the slopes retain remnants of the spring annual chisos bluebonnet (*Lupinus havardii*). Present in both transects, the chisos bluebonnet occupied an average of 11% of the total coverage on the slopes.

THE ALLUVIAL GRAVEL ASSOCIATION

Although similar in composition to the alluvial gravels of the Fresno Creek area, the association is far more restricted, extending from the foot of the Bofecillos Mountains southward in a band parallel to the Rio Grande. This area is characterized by a fairly level terrain which is frequently dissected by numerous minor drainage systems. Creosote is the dominant shrub throughout this association. In a quadrat transect north of the highway across from Closed Canyon (see map), creosote occupied 18.8% of the total coverage. Dominant herbaceous species were leatherstem with 22.7% of total coverage and tasajilla with 14.78%. Engelmann prickly pear and pitaya were additional cacti found in abundance. The paucity of grasses is reflected in a total relative dominance of 3.4% (Table 3, Fig. 3). Grass cover was composed of fluffgrass, common curlymesquite, and wolftail.

The alluvial gravels situated near the confluence of several of the minor drainages feature a finer soil texture in addition to larger amounts of available water. A greater diversity of plants is thus supported, including shrubs such as mescat acacia, catclaw acacia, mesquite, lotebush, guayacan, and spiny hackberry.

THE RIPARIAN ASSOCIATION

An intricate maze of drainages exists throughout the plains region. However, the riparian association, as recognized in this study, is restricted to the major streambeds which result from drainage from the canyons (Fig. 4). For instance, Panther Creek is fed by the periodic runoff of rainwater from three main branches of Panther Canyon (see map). Here the water table is within reach of the root systems of water-loving plants such as desert willow (*Chilopsis linearis*), burro bush (*Hymenoclea monogyra*), seep willow (*Baccharis glutinosa*), and button bush (*Cephalanthus occidentalis*). Plants such as mesquite and catclaw acacia that are commonly found on the slopes and alluvial gravels are scattered in the streambed and typically exhibit increased stature and more luxuriant foliage.

THE CANYON ASSOCIATION

The combination of topography and water supply is a primary force in determining the plant composition within the various canyons. Most of the surface water is intermittent, depending on the quantity of rainfall. The water table is relatively shallow and thus is accessible to a well-developed root system. In the portions of the canyons that are narrow, the sheer walls offer protection from intense sunlight and wind. The lower temperatures and reduced water loss provide a more favorable environment that allows for the presence of typical canyon elements such as evergreen sumac, Mexican buckeye, esperanza, poreleaf, brickellbush, desert willow, and an occasional blue-star (*Amsonia arenaria*).

Permanent water sources are highly localized and center exclusively around springs that are scattered throughout the canyons. Near the springs a lush vegetation abounds that is reminiscent of the canyons and arroyos of Fresno Creek (Fig. 5). Willow, cottonwood, ash, and seepwillow are present, in addition to vines such as canyon grape, ivy treebine (*Cissus incisa*), and poison ivy. The shallow pools support a diversity of herbaceous wet-area species, the more common of which include cattail, water hyssop, spikesedge, flatsedge, and the cardinal flower. Numerous grass species, including dallis grass (*Paspalum dilalatum*), witchgrass (*Leptoloma cognatum*), cockspur (*Echinochloa colonum*), burgrass grass (*Tragus berteronianus*), slim tridens (*Tridens muticus*), arizona cottentop (*Trichachne californica*), New Mexico lovegrass (*Eragrostis neomexicana*), and bentgrass (*Agrostis semiverticillata*), are found in the vicinity of these springs.

Panther Canyon and Canyon Madera are both fairly wide, with a series of terraces and gradual slopes grading toward the neighboring cliffs. It is in these areas that significant overlap between the canyon and slope association exists. Dense growths of mesquite and catclaw acacia frequent the streambed. The terraces just above feature spiny hackberry, creasote, lotebush, Spanish dagger, leatherstem, mescat acacia, guayacan, ocotillo, mormon tea (*Ephedra aspera*), lechugilla, and prickly-pear.

Numerous herbs, both annuals and perennials, are scattered along the dry streambeds of these canyons. Some of the more frequent taxa are rag sumpweed (*Iva ambrosiaefolia*), desert tobacco (*Nicotiana trigonophylla*), spiderling (*Boerhaavia intermedia*), *Nama havardii*, desert baileya, hairy seed bahia (*Bahia absinthifolia*), snapdragon vine (*Maurandya antirrhiniflora*) yellow rocknettle (*Eucnide bartonioides*), limoncillo (*Pectis papposa*), and *Hedeoma drummondii.* Some of the perennials with tubers or a well-developed fibrous root system may be able to withstand the periodic inundations of water so characteristic of these canyons. The annuals and short-lived perennials are able to become quickly established, flower, and set seed before the fall rains appear. However, the general paucity of herbaceous ground cover in the streambed indicates the force of these floods which leave only the larger shrubs and trees intact.

THE RIVER ASSOCIATION

Confined to the sandy-silt terraces and flood plains of the Rio Grande, the river association is often characterized by dense growths of vegetation (Fig. 6). Unlike the other communities in which the species are predominantly native to Texas, many of the dominant plants found along the river are introduced. Carizzo, a native of the Mediterranean region and tropical Asia, is the dominant grass of the river. A more humble grass, locally abundant along the river is Bermuda grass, a species introduced from India. The salt cedar, also a native of India, is a dominant tree which grows in some places to the exclusion of other species. Tree tobacco with its bluish leaves and yellow tubular flowers is an introduction from South America that is successful along the river banks. Seepwillow, mesquite, yerbade, and salt heliotrope represent native species that frequent this association.

In contrast to the relatively wide river valley along much of the Rio Grande, Colorado Canyon is characterized by abrupt, scattered sand and gravel bars. Ash, western soapberry (*Sapindus saponaria*), evergreen sumac, canyon grape, and poison ivy appear sporadically as do the previously mentioned plants of this association. Herbs such as sunflower (*Helianthus annuus*) and devilweed (*Aster spinosus*) are locally abundant on sandy banks of the canyon. An interesting grass inhabiting the canyon is spidergrass (*Aristida ternipes*). Belonging to the three-awn grasses in which each spikelet bears three awns, this species is distinct in having only the central awn developed while the lateral awns are minute. Spidergrass typically grows on slopes at higher elevations.

RARE SPECIES

Machaeranthera gypsophila is a recently described species (Turner 1973) collected just west of Closed Canyon (see map). Although occurring as Coahuila and Socorra County, New Mexico, this is the only known locality for this species in Texas. This stout perennial produces showy flowering heads with white rays and a yellow disk. As with many desert plants, flowering is opportunistic and usually follows periods of significant rainfall.

Tapado Canyon, which is abundantly supplied with springs, supports a population of big cenchrus (*Cenchrus myosuroides*). This grass was growing in a pool with cattail and poison ivy. Unlike the small but ubiquitous coastal sandbur (*Cenchrus incertus*), *Cenchrus myosuroides* is a robust grass with culms up to 2 m high. Although infrequent in the Rio Grande Plains, this native cenchrus is considered to be rare in the Trans-Pecos region.

One species is endemic to southern Brewster and Presidio counties. *Euphorbia simulans* is an inconspicuous prostrate herb with milky sap, minute flowers and a zigzag branching pattern. This rare spurge can be found along the gravelly streambed of Panther Creek.

SUMMARY AND COMPARISON OF SOLITARIO, FRESNO CREEK AND COLORADO CANYON

The Solitario, as the name implies, remains distinct from the Fresno Creek and Colorado Canyon areas in a number of features. Heath cliffrose (*Cowania ericaefolia*), toothed service-berry, Gregg ash, Arizona oak (*Quercus arizonica*), Gray oak (*Quercus grisea*), redberry juniper (*Juniperus pinchotii*), and rough mortonia were collected only from the Solitario. Their restriction may be a result of the structure of this geological formation itself since it forms a partial barrier to seed dispersal. Environmental factors such as temperature, edaphic properties, water supply, or altitude may also prohibit the establishment of these plants in the other areas.

Another distinguishing feature of the Solitario is the lack of a permanent water supply. All the drainages are dependent upon ample rainfall in order to run, in contrast to Fresno Creek with its water falls and springs and to Colorado Canyon with the Rio Grande and numerous springs along the northward-running canyons. As a result of a permanent water source, Fresno Creek and Colorado Canyon contain fecund "oases" that nurture growths of sedges, rushes, ferns, and numerous grasses, along with ash (*Fraxinus velutina*) and cottonwood (*Populus arizonica*).

The slope community is for the most part continuous throughout. Distribution of sotol appears to follow an altitudinal gradient, for it is a characteristic element in the Solitario and higher slopes along Fresno Creek but is conspicuously absent from the slopes of the Colorado Canyon area. Increased aridity and grazing pressures in these latter two areas may be responsible for the relative abundance of lechuguilla and leatherstem as compared to the slopes of the Solitario.

The alluvial gravel association is fairly consistent except that creosote is far more extensive in the Fresno Creek and Colorado Canyon areas than in the Solitario. Once again an altitudinal phenomenon may be involved, resulting in higher temperatures and increased water-loss at the lower elevations. Man may have had a stronger impact on the vegetation of Fresno Creek and Colorado Canyon, resulting in further deterioration of grasslands, followed by the invasion of desert shrubs such as creosote. The isolation of the Solitario is also reflected by the scarcity of introduced species. This situation is in sharp contrast to the Colorado Canyon area where introductions such as salt cedar (*Tamarix gallica*), tree tobacco (*Nicotiana glauca*), and giant reed (*Arundo donax*) predominate along the Rio Grande.

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APPENDIX I

Localities for quadrat transects presented in Tables I-III.

Table I—Southwest facing slope of Santana Mesa, just south of Panther Canyon (Santana Mesa 7.5-minute quadrangle map).

Table II—North facing slope of Mesa just west of Closed Canyon (Redford SE 7.5-minute quadrangle map).

Table III—Alluvial gravel plain north of the highway and across from Closed Canyon (Redford SE 7.5-minute quadrangle map).

APPENDIX II

Explanation of symbols used in tables.

Q = Total quadrats in which species occured.

RFi = Raw Frequency = Present quadrats in which species occurred.

$$\text{RFii} = \text{Relative Frequency} = \frac{\text{Q of species}}{\text{Total Q}}$$

$$\text{RDi} = \text{Relative Density} = \frac{\text{Total individuals of species}}{\text{Total individuals of all species}}$$

TI = Total Individuals

$$\text{RC} = \text{Raw Cover} = \frac{\text{Total area covered by species}}{\text{Total area sampled}}$$

$$\text{RDii} = \text{Relative Dominance} = \frac{\text{Area covered by species}}{\text{Area covered by all species}}$$

TA = Index of the total area covered by species

FIGURE 1

The Slope Association – site for Quadrant Transect 12.

TABLE I

Quadrat Transect 12

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida wrightii	4	10.0	3.51	3.18	5	6.00	12.56	240
Bouteloua ramosa	7	17.5	6.14	6.37	10	4.95	10.36	198
Erioneuron pulchellum	6	15.0	5.26	5.73	9	0.55	1.15	22
Muhlenbergía monticola	19	57.5	16.67	16.56	26	6.00	12.56	240
Stipa eminens	3	7.5	2.63	3.82	6	1.75	3.66	70
HERBS								
Agave lechequilla	1	2.5	0.88	0.64	1	0.25	0.52	10
Allionia incarnata	15	37.5	13.16	15.92	25	11.75	24.59	470
Argythamnia neomexicana	1	2.5	0.88	0.64	1	0.12	0.26	5
Bahia absinthifolia	2	5.0	1.75	1.27	2	0.32	0.68	13
Cevallia sinuata	3	7.5	2.63	1.91	3	0.22	0.44	9
Cassia bauhinioides	1	2.5	0.88	1.27	2	0.50	1.05	20
Chamaesaracha villosa	3	7.5	2.63	3.18	5	0.57	1.20	23
Croton dioicus	2	5.0	1.75	1.91	3	0.87	1.83	35
Croton pottsii	8	20.0	7.02	5.10	8	0.77	1.62	31
Euphorbia eriantha	8	20.0	7.02	5.10	8	0.77	1.62	31
Hedeoma drummondii	1	2.5	0.88	0.64	1	0.12	0.26	5
Helianthus ciliaris	1	2.5	0.88	0.64	1	0.02	0.05	1
Iva ambrosiaefolia	4	10.0	3.51	5.10	8	0.40	0.84	16
Jatropha dioica	6	15.0	5.26	4.46	7	4.62	9.68	185
Lupinus havardii	10	25.0	8.77	10.83	17	3.62	4.59	145
Nerisyrenia camporum	1	2.5	0.88	0.64	1	0.07	0.16	3
Polygala longa	1	2.5	0.88	0.64	1	0.07	0.16	3
Tragia ramosa	3	7.5	2.63	1.91	3	0.27	0.58	11
TREES & SHRUBS								
Porlieria angustifolia	1	2.5	0.88	0.64	1	0.25	0.52	10
Prosopis glandulosa	3	7.5	2.63	1.91	3	2.87	6.02	115
TOTAL	114		100.01%	100.01%	157	47.70%	99.99%	1911%

FIGURE 2

The Slope Association — site for Quadrant Transect 13.

TABLE II

Quadrat Transect 13

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida wrightii	5	12.5	4.76	3.39	6	1.37	2.95	55
Bouteloua ramosa	18	45.0	17.14	12.99	23	15.70	33.71	628
Erioneuron pulchellum	2	5.0	1.90	2.26	4	0.17	0.38	7
Hilaria berlandieri	3	7.5	2.86	10.73	19	2.75	5.90	110
Lycurus phleoides	1	2.5	.95	0.56	1	0.12	0.27	5
HERBS								
Agave lechequilla	4	10.0	3.81	2.26	4	1.37	2.95	55
Bahia absinthifolia	4	10.0	3.81	7.91	14	0.77	1.66	31
Baileya multiradiata	1	2.5	0.95	0.56	1	0.05	0.11	2
Cryptantha mexicana	2	5.0	1.90	1.13	2	0.12	0.27	5
Dyssodia pentachaeta	4	10.0	3.81	4.52	8	0.47	1.02	19
Hedeoma drummondii	6	15.0	5.71	4.52	8	0.57	1.23	23
Jatropha dioica	4	10.0	3.81	2.82	5	1.75	3.76	70
Lupinus havardii	22	55.0	20.95	25.42	45	6.80	14.60	272
Machaeranthera gypsophila	7	17.5	6.67	6.78	12	2.57	5.26	98
Machaeranthera scabrella	3	7.5	2.86	1.69	3	1.07	2.31	43
Menodora longiflora	2	5.0	1.90	1.13	2	0.57	1.23	23
Opuntia leptocaulis	3	7.5	2.86	1.69	3	1.37	2.95	55
Ruellia parryi	3	7.5	2.86	2.26	4	0.62	1.34	25
Selaginella lepidophylla	1	2.5	0.95	1.69	3	0.37	0.80	15
TREES & SHRUBS								
Krameria grayi	2	5.0	1.90	1.13	2	2.05	4.40	82
Larrea tridentata	6	15.0	5.71	3.39	6	5.12	11.00	205
Opuntia phaeacantha	2	5.0	1.90	1.13	2	0.87	1.88	35
	105		99.97%	99.96%	177	46.62%	99.98%	1863%

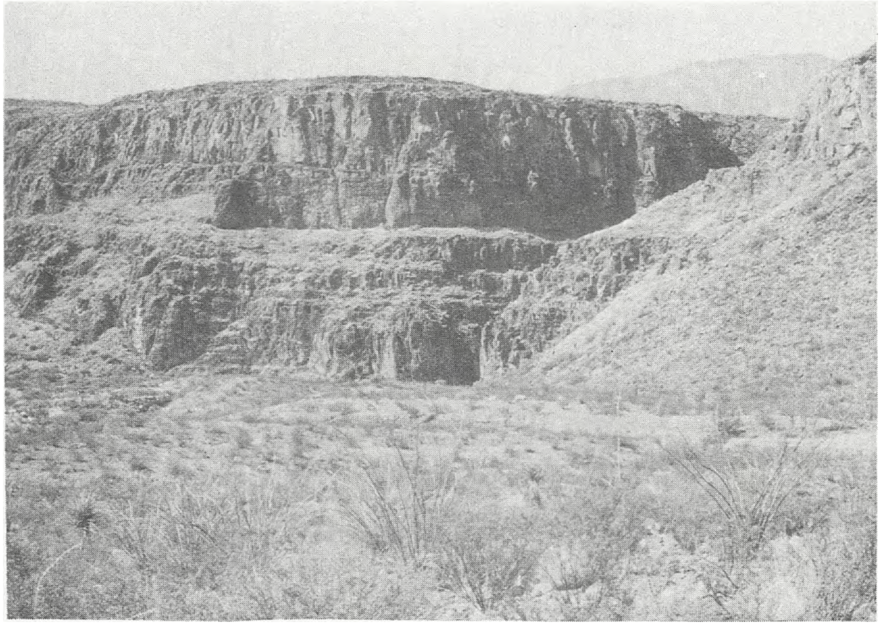

FIGURE 3

The Alluvial Gravel Association — site for Quadrant Transect 14.

TABLE III

Quadrat Transect 14

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Erioneuron pulchellum	8	13.33	6.78	7.98	13	0.55	1.37	33
Hilaria berlandieri	1	1.66	0.85	4.29	7	0.58	1.45	35
Lycurus phleoides	1	1.66	0.85	1.84	3	0.25	0.62	15
HERBS								
Agave lechequilla	1	1.66	0.85	0.61	1	0.08	0.20	5
Argythamnia neomexicana	3	5.00	2.54	1.84	3	0.20	0.50	12
Bahia absinthifolia	7	11.66	5.93	4.29	7	0.40	0.99	24
Bahia pedata	23	38.33	19.49	27.61	45	2.05	5.09	123
Baileya multiradiata	1	1.66	0.85	0.61	1	0.08	0.20	5
Boerhaavia intermedia	6	10.00	5.08	5.52	9	1.05	2.57	62
Cassia bauhinioides	2	3.33	1.69	1.23	2	0.30	0.83	20
Chamaesaracha villosa	1	1.66	0.85	0.61	1	0.16	0.41	10
Coldenia canescens	1	1.66	0.85	0.61	1	0.50	1.24	30
Croton pottsii	1	1.66	0.85	0.61	1	0.25	0.62	15
Jatropha dioica	12	20.00	10.17	7.98	13	9.16	22.76	550
Lupinus havardii	10	16.67	8.47	9.20	15	2.38	5.92	143
Nama hispida	1	1.66	0.85	1.23	2	0.03	0.08	2
Opuntia leptocaulis	11	18.33	9.32	6.75	11	5.95	14.78	357
Tragia ramosa	2	3.33	1.69	1.23	2	0.03	0.08	2
Trixis californica	3	5.00	2.54	1.84	3	1.25	3.10	75
TREES & SHRUBS								
Acacia neovernicosa	5	8.33	4.24	3.07	5	3.03	7.53	182
Acacia greggii	1	1.66	0.85	0.61	1	1.66	4.14	100
Fouquieria splendens	3	5.00	2.54	1.84	3	0.60	1.49	36
Larrea tridentata	10	16.67	8.47	6.13	10	7.58	18.83	455
Opuntia phaeacantha	4	6.66	3.39	2.45	4	2.08	5.17	125
	118		99.9%	99.98%	163	40.20%	99.97%	2416%

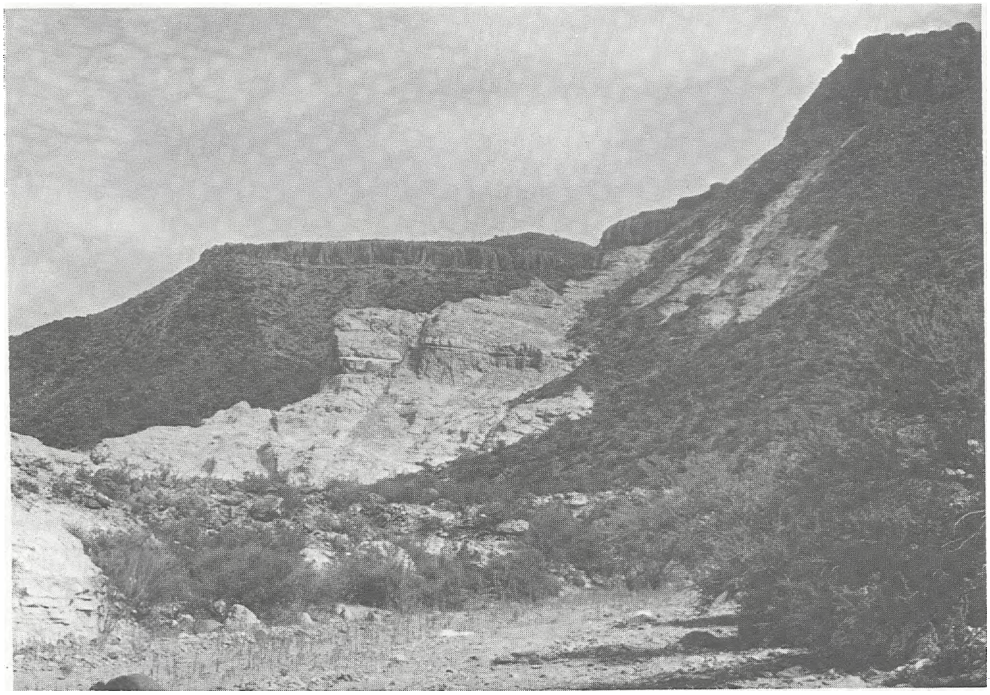

FIGURE 4

The Riparian Association – catclaw acacia, seep willow and mesquite inhabiting the open drainage at the mouth of Tapado Canyon.

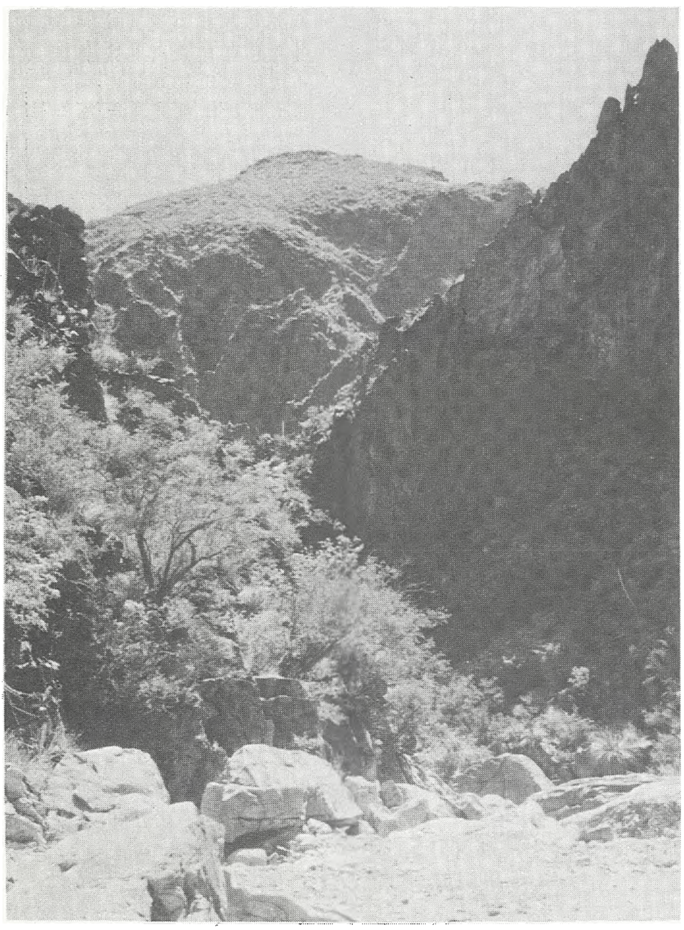

FIGURE 5

The Canyon Association – as represented by Tapado Canyon.

FIGURE 6

The Mouth of Colorado Canyon on the Rio Grande River.

COLORADO CANYON SPECIES LIST

A – Annual
P – Perennial
I – Introduced
N – Native
* – Endemic or Rare

SCIENTIFIC NAME		COMMON NAME
SELAGINELLACEAE		SPIKEMOSS FAMILY
Selaginella lepidophylla (Hook. & Grev.) Spring	NP	Resurrection Plant, Siempre Viva
Selaginella peruviana (Milde.) Hieron.	NP	
POLYPODIACEAE		TRUE FERN FAMILY
Adiantum capillus-veneris L.	NP	Maidenhair Fern, Culantrillo
Cheilanthes horridula Maxon	NP	Rough Lipfern
EPHEDRACEAE		EPHEDRA FAMILY
Ephedra antisyphilitica C.A. Mey	NP	Clapweed, Popote
Ephedra aspera Engelm.	NP	Boundary Ephedra, Popotilla
Ephedra trifurca Torr.	NP	Longleaf Ephedra, Canatilla
TYPHACEAE		CAT-TAIL FAMILY
Typha latifolia L.	NP	Common Cat-Tail, Tule Espadilla
POACEAE		GRASS FAMILY
Agrostis semiverticillata (Forsk.) Christ	NP	Water Bentgrass
Aristida ternipes Cav.	NP	Spider Grass
Aristida wrightii Nash	NP	Wright Three-Awn
Arundo donax L.	NP	Giant Reed, Carrizo
Bothriochloa saccharoides (Swartz.) Rydb.	NP	Silver Beardgrass
Bouteloua barbata Lag.	NA	Sixweeks Grama
Bouteloua curtipendula (Michx.) Torr.	NP	Side-Oats Grama
Bouteloua gracilis (H.B.K.) Griffiths	NP	Blue Grama
Bouteloua ramosa Vasey	NP	Chino Grama, Chinograss
**Cenchrus myosuroides* H.B.K.	NP	Big Cenchrus, Big Sandbur
Cynodon dactylon (L.) Pers.	IP	Bermuda Grass, Pata de Gallo
Echinochloa colonum (L.) Link	IA	Jungle-Rice
Eragrostis neomexicana Vasey	NA	New Mexico Lovegrass
Erioneuron pulchellum (H.B.K.) Tateoka	NP	Fluffgrass
Hilaria mutica (Buckl.) Benth.	NP	Tobosa
Leptoloma cognatum (Schult.) Chase	NP	Fall Witchgrass
Lycurus phleoides H.B.K.	NP	Wolftail
Muhlenbergia monticola Buckl.	NP	Mesa Muhly
Muhlenbergia porteri Scribn.	NP	Bush Muhly, Mesquite-Grass
Pappophorum mucronulatum Nees	NP	Whiplash Pappusgrass
Paspalum dilatatum Poir.	IP	Dallas Grass
Setaria geniculata (Lam.) Beauv.	NP	Knotroot Bristlegrass
Setaria leucopila (Scribn. & Merr.) K. Schum.	NP	
Sporobolus airoides (Torr.) Torr.	NP	Alkali Sacaton
Sporobolus contractus Hitchc.	NP	Spike Dropseed
Stipa eminens Cav.	NP	Southwestern Needlegrass
Tragus berteronianus Schult.	IA	Spike Burgrass
Trichachne californica (Benth.) Chase	NP	Arizona Cottontop
Tridens muticus (Torr.) Nash	NP	Slim Tridens

SCIENTIFIC NAME		COMMON NAME
CYPERACEAE		SEDGE FAMILY
Cyperus laevigatus L.	NP	Smooth Flatsedge
Eleocharis macrostachya Britt.	NP	Large Spikesedge
Eleocharis montevidensis Kunth	NP	Sand Spikesedge
Fuirena simplex Vahl.	NP	Western Umbrellasedge
COMMELINIACEAE		SPIDERWORT FAMILY
Commelina erecta L. var. *angustifolia* (Michx.) Fern.	NP	Hierba del Pollo
JUNCACEAE		RUSH FAMILY
Juncus nodosa L.	NP	Jointed Rush
LILIACEAE		LILY FAMILY
Nolina erumpens (Torr.) Wats.	NP	Bear Grass
Yucca thompsoniana Trel.	NP	Thompson Yucca
Yucca torreyi Shafer	NP	Torrey Yucca
AMARYLLIDACEAE		AMARYLLIS FAMILY
Agave lecheguilla Torr.	NP	Lechuguilla
SALICACEAE		WILLOW FAMILY
Populus arizonica Sarg.	NP	Arizona Cottonwood, Chopo
Salix gooddingii Ball var. *variabilis* Ball	NP	Southern Black Willow
JUGLANDACEAE		WALNUT FAMILY
Juglans microcarpa Berl.	NP	Little Walnut
ULMACEAE		ELM FAMILY
Celtis pallida Torr.	NP	Granjeno, Desert Hackberry
Celtis reticulata Torr.	NP	Palo Blanco, Netleaf Hackberry
URTICACEAE		NETTLE FAMILY
Parietaria obtusa Rydb.	NP	
VISCACEAE		MISTLETOE FAMILY
Phoradendron tomentosum (DC.) Gray	NP	Injerto
ARISTOLOCHIACAEA		BIRTHWORT FAMILY
Aristolochia coryi I.M. Johnst.	NP	Cory Dutchman's Pipe
POLYGONACEAE		KNOTWEED FAMILY
Eriogonum jamesii Benth.	NA	James Wildbuckweed
Eriogonum rotundifolium Benth.	NA	Roundleaf Wildbuckweed
Rumex pulcher L.	IP	Fiddle Dock
CHENOPODIACEAE		GOOSEFOOT FAMILY
Atriplex canescens (Pursh) Nutt.	NP	Four-Wing Saltbush
Atriplex obovata Moq.	NP	Silver Saltbush
Chenopodium leptophyllum Nutt.	NA	Slimleaf Goosefoot
AMARANTHACEAE		AMARANTHUS FAMILY
Amaranthus torreyi (Gray) Wats.	NA	
Froelichia arizonica Thornb.	NP	Arizona Snakecotton
Tidestromia lanuginosa (Nutt.) Standl. var. *lanuginosa*	NA	Espanta Vaqueros

SCIENTIFIC NAME		COMMON NAME
NYCTAGINACEAE		FOUR-O'CLOCK FAMILY
Acleisanthes longiflora Gray	NP	Angel Trumpets
Allionia incarnata L.	NP	Pink Windmills, Hierba de la Hormiga
Boerhaavia intermedia E.M. Jones	NA	Spreading Spiderling
Commicarpus scandens (L.) Standl.	NP	Climbing Wartclub, Pega-Polla
Mirabilis linearis (Pursh) Heimerl.	NP	Linearleaf Four-O'Clock
Selinocarpus angustifolius Torr.	NP	Narrowleaf Moonpod
PHYTOLACCACEAE		POKEWEED FAMILY
Rivina humilis L.	NP	Pigeon-Berry, Coralito
PORTULACACEAE		PURSLANE FAMILY
Portulaca mundula I.M. Johnst.	NA	Shaggy Portulaca, Chisme
Portulaca oleracea L.	NA	Purslane, Verdolaga
Talinum angustissimum (Gray) Woot. & Standl.	NP	Orange Flameflower
RANUNCULACEAE		CROWFOOT FAMILY
Clematis alpina Mill.	NP	Alpine Clematis
Clematis drummondii T. & G.	NP	Texas Virgin's Bower
PAPAVERACEAE		POPPY FAMILY
Argemone chisosensis G. B. Ownbey	NA	Chisos Pricklepoppy
CRUCIFERAE		MUSTARD FAMILY
Lepidium virginicum L. var. *medium* (Greene) H.L. Hitchc.	NA	Virginia Pepperweed, Lentejilla
Lesquerella fendleri (Gray) Wats.	NP	Fendler Bladderpod
Lesquerella purpurea (Gray) Wats.	NP	Rose Bladderpod
Nerisyrenia camporum (Gray) Greene	NP	Mesa Greggia
Rorippa nasturtium-aquaticum (L.) Hayek	IP	Water-Cress
Sisymbrium linearifolium (Gray) Payson	NP	
CAPPARIDACEAE		CAPER FAMILY
Polanisia dodecandra (L.) DC. var. *trachysperma* (T. & G.)	NA	Roughseed Clammyweed
RESEDACEAE		MIGNONETTE FAMILY
Oligomeris linifolia (Vah.) Macbr.	NA	
ROSACEAE		ROSE FAMILY
Fallugia paradoxa (Don.) Endl.	NP	Apache-Plume
Prunus havardii Wright	NP	Havard Plum
LEGUMINOSAE		LEGUME FAMILY
Acacia constricta Gray	NP	Mescat Acacia
Acacia greggii Benth.	NP	Catclaw
Acacia neovernicosa Isley		
Astragalus emoryanua (Rydb.) Cory var. *emoryanus*	NA	Emory Milkvetch
Cassia bauhinioides Gray	NP	Two-Leaved Senna
Cassia lindheimeriana Scheele	NP	Lindheimer Senna
Cassia wislizenii Gray	NP	Wislizenus Senna
Dalea neomexicana (Gray) Cory	NP	New Mexico Dalea
Lupinus havardii Wats.	NA	Chisos Bluebonnet
Mimosa biuncifera Benth.	NP	Cat's-Claw Mimosa
Phaseolus wrightii Gray	NP	Wright Bean
Prosopis glandulosa Torr. var. *torreyana* (L. Benson) M.C. Johnst.	NP	Western Honey Mesquite

SCIENTIFIC NAME		COMMON NAME
Rhynchosia texana Torr. & Gray	NP	Texas Stoutbean
Sophora secundiflora (Ort.) DC.	NP	Texas Mountain Laurel, Frijolillo
KRAMERIACEAE		RATANY FAMILY
Krameria grayi Rose & Painter	NP	White Ratany
ZYGOPHYLLACEAE		CALTROP FAMILY
Larrea tridentata (DC.) Cov.	NP	Creosote Bush, Gobernadora
Porlieria angustifolia (Engelm.) Gray	NP	Guayacan, Soap-Bush
POLYGALACEAE		MILKWORT FAMILY
Polygala longa Gray	NP	Milkwort
Polygala scoparioides Gray	NP	Milkwort
EUPHORBIACEAE		SPURGE FAMILY
Argythamnia neomexicana Muell.	NP	New Mexico Wildmercury
Croton dioicus Cav.	NP	Rosval, Hierba del Gato
Croton pottsii (Kl.) Muell. Arg.	NP	Leather-Weed
Croton sancti-lazari Croizat	NP	
Euphorbia albomarginata T. & G.	NP	Whitemargin Euphorbia
Euphorbia eriantha Benth.	NA	Woolly-Flower Euphorbia
Euphorbia hyssopifolia L.	NA	Hyssopleaf Euphorbia
Euphorbia pycnanthema Engelm.	NP	Head Euphorbia
**Euphorbia simulans* (Wheeler) Warnock & M.C. Johnst.	NP	
Euphorbia theriaca L.C. Wheeler	NA	Terlingua Euphorbia
Jatropha dioica Cerv. var. *graminea* McVaugh	NP	Sangre de Drago, Leatherstem
Tragia ramosa Torr.	NP	Catnip Noseburn
ANACARDIACEAE		SUMAC FAMILY
Rhus toxicodendron L.	NP	Poison Ivy, Hiedra
Rhus virens Gray	NP	Evergreen Sumac, Lentisco
SAPINDACEAE		SOAP-BERRY FAMILY
Sapindus saponaria L. var. *drummondii* (H. & A.) L. Benson	NP	Jaboncillo, Western Soapberry
Ungnadia speciosa Endl.	NP	Mexican Buckeye, Monilla
RHAMNACEAE		BUCKTHORN FAMILY
Ziziphus obtusifolia (T. & G.) Gray var. *obtusifolia*	NP	Lotebush, Clepe
VITACEAE		GRAPE FAMILY
Cissus incisa (Nutt.) Des Moul.	NP	Hierba del Buey, Ivy Treebine
Vitis arizonica Engelm. var. *arizonica*	NP	Canyon Grape
Vitis arizonica Engelm. var. *glabra* Munson	NP	Canyon Grape
MALVACEAE		MALLOW FAMILY
Abutilon incanum (Link) Sweet	NP	Indian Mallow, Tronadora
Abutilon malacum Wats.	NP	
Abutilon parvulum Gray	NP	Littleleaf Abutilon
Abutilon wrightii Gray	NP	Wright's Abutilon
Herissantia crispa (L.) Brizicky	NA	Netvein Mallow, Colotahue
Hibiscus denudatus Benth.	NP	Pale-Face, Rose-Mallow
Sida hederacea (Hook.) Gray	NP	Dollar-Weed, Alkali Mallow
Sphaeralcea angustifolia (Cav.) D. Don	NP	Narrowleaf Globemallow

SCIENTIFIC NAME		COMMON NAME
TAMARICACEAE		TAMARISK FAMILY
Tamarix aphylla (L.) Karst.	IP	
FOUQUIERIACEAE		OCOTILLO FAMILY
Fouquieria splendens Engelm.	NP	Ocotillo
KOEBERLINIACEAE		ALLTHORN FAMILY
Koeberlinia spinosa Zucc.	NP	Junco, Allthorn
LOASACEAE		STICKLEAF FAMILY
Cevallia sinuata Lag.	NP	Stinging Cevallia
Eucnide bartonioides Zucc.	NA	Yellow Rocknettle
Mentzelia oligosperma Sims	NP	Chicken Thief, Stickleaf
CACTACEAE		CACTUS FAMILY
Echinocereus enneacanthus Engelm. var. *stramineus* (Engelm.) L. Benson	NP	Strawberry Cactus
Echinocereus pectinatus (Scheidw.) Engelm. var. *neomexicana* (Coult.) L. Benson	NP	Rainbow Cactus
Echinocereus triglochidatus Engelm.	NP	Claret-Cup
Epithelantha micromeris (Engelm.) Weber	NP	Button-Cactus
Mammillaria pottsii Scheer	NP	Potts Mammillaria
Opuntia imbricata (Haw.) DC.	NP	Tree Cholla, Coyonostle
Opuntia leptocaulis DC.	NP	Christmas Cactus, Tasajillo
Opuntia phaeacantha Engelm. var. *discata* (Engelm.) L. Benson & Walkington	NP	Engelmann Prickly-Pear
Opuntia rufida Engelm.	NP	Blind Prickley-Pear
Opuntia schottii Engelm.	NP	Clavellina
Opuntia violacea Engelm.	NP	Purple Prickly-Pear
ONAGRACEAE		EVENING PRIMROSE FAMILY
Gaura coccinea Pursh	NP	Scarlet Gaura
PRIMULACEAE		PRIMROSE FAMILY
Samolus cuneatus Small	NP	Limerock Broadweed
EBENACEAE		EBONY FAMILY
Diospyros texana Scheele	NP	Mexican Persimmon
OLEACEAE		OLIVE FAMILY
Forestiera angustifolia Torr.	NP	Desert Olive, Panalero
Fraxinus velutina Torr.	NP	Mexican Ash, Fresno
Menodora longiflora Gray	NP	Showy Menodora, Twin-Pod
LOGANIACEAE		LOGANIA FAMILY
Buddleja marrubiifolia Benth.	NP	Woolly Butterfly Bush
GENTIANACEAE		GENTIAN FAMILY
Eustoma exaltatum (L.) Salisb.	NA	Tall Prairiegentian
APOCYNACEAE		DOGBANE FAMILY
Amsonia arenaria Standl.	NP	Woolly Silmpod
ASCLEPIADACEAE		MILKWEED FAMILY
Asclepias oenotheroides Cham. & Schlecht.	NP	Hierba de Zizotes
Sarcostemma cynanchoides Decne. var. *hartwegii* (Vail) Shinners	NP	

SCIENTIFIC NAME		COMMON NAME
CONVOLVULACEAE		MORNING GLORY FAMILY
Evolvulus alsinoides L. var. *angustifolia* Torr.	NP	Ojo de Vibora
Ipomoea sp.		
HYDROPHYLLACEAE		WATERLEAF FAMILY
Nama havardii Gray	NA	Havard Nama
Nama hispidum Gray	NA	Rough Nama
Phacelia congesta Hook.	NA	Spike Phacelia
Phacelia robusta (Macbr.) I.M. Johnst.	NA	Stout Phacelia
BORAGINACEAE		BORAGE FAMILY
Coldenia canescens DC.	NP	Gray Coldenia, Oreja de Perro
Cryptantha mexicana (Brandeg.) I.M. Johnst.	NA	Mexican Cryptantha
Heliotropium curassavicum L. var. *curassivivum*	NP	Quailplant, Cola de Mico
VERBENACEAE		VERVAIN FAMILY
Aloysia gratissima (Gill. & Hook.) Troncoso	NP	Common Bee-Bush, Palo Amarillo
Aloysia wrightii (Gray) Heller	NP	Oreganillo
Lantana macropoda Torr.	NP	Desert Lantana, Mejorana
Phyla strigulosa (Mart. & Gal.) Moldenke	NP	Diamondleaf Frog-Fruit
Verbena neomexicana (Gray) Small var. *hirtella* Perry	NP	Hillside Vervain
LABIATAE		MINT FAMILY
Hedeoma drummondii Benth. var. *drummondii*	NP	Drummond Hedeoma
Marrubium vulgare L.	IP	Common Horehound, Marrubio
Salvia regla Cav.	NP	Mountain Sage
Scutellaria drummondii Benth.	NP	Drummond Skullcap
SOLANACEAE		POTATO FAMILY
Chamaesaracha villosa Rydb.	NP	
Datura wrightii Regel.	NA	Indian Apple, Sacred Datura
Nicotiana trigonophylla Dunal	NA	Desert Tobacco, Tabaquillo
Petunia parviflora Juss.	IA	Wild Petunia, Seaside Petunia
Physalis subulata Rydb. var. *neomexicana* (Rydb.) Waterfall	NA	
Solanum eleagnifolium Cav.	NP	Silverleaf Nightshade, Trompillo
SCROPHULARIACEAE		FIGWORT FAMILY
Bacopa monnieri (L.) Wettst.	NP	Coastal Waterhyssop
Maurandya antirrhinifolia Humb. & Bonpl.	NP	Snapdragon Vine
Mimulus glabratus H.B.K.	NP	Monkeyflower
Penstemon baccharifolius Hook.	NP	Charisleaf Penstemon
Penstemon havardii Gray	NP	Havard Penstemon
BIGNONIACEAE		CATALPA FAMILY
Chilopsis linearis (Cav.) Sweet	NP	Desert Willow, Mimbre
Tecoma stans (L.) Juss. var. *angustata* Rehd.	NP	Trumpet-Flower, Esperanza
OROBANCHACEAE		BROOMRAPE FAMILY
Orobanche cooperi (Gray) Heller	NP	Broom-Rape
ACANTHACEAE		ACANTHUS FAMILY
Carlowrightia arizonica Gray	NP	
RUBIACEAE		MADDER FAMILY
Cephalanthus occidentalis L.	NP	Common Buttonbush, Honey-Balls

SCIENTIFIC NAME		COMMON NAME
Galium microphyllum Gray	NP	Bracted Bedstraw
Hedyotis nigricans (Lam.) Fosb. var. *rigidiuscula* (Gray) Shinners	NP	Stiff Bluets
CUCURBITACEAE		GOURD FAMILY
Ibervillea tenuisecta (Gray) Small	NP	Slimlobe Globeberry
CAMPANULACEAE		BLUEBELL FAMILY
Lobelia cardinalis L. var. *pseudosplendens* McVaughn	NP	Cardinal-Flower
COMPOSITAE		SUNFLOWER FAMILY
Artemisia ludoviciana Nutt.	NP	Western Mugwort
Baccharis glutinosa (R. & P.) Pers.	NP	Jara, Seepwillow
Bahia absinthifolia Benth.	NP	Hairyseed Bahia
Bahia pedata Gray	NA	Bluntscale Bahia
Baileya multiradiata Harv. & Gray	NA	Desert Baileya
Brickellia coulteri Gray	NP	Coulter Brickelbush
Brickellia laciniata Gray	NP	Splitleaf Brickelbush
Conyza canadensis (L.) Cronq. var. *glabratus* (Gray) Cronq.	NA	Horse-Weed
Dyssodia pentachaeta (DC.) Robinson	NP	Parralena, Common Dogweed
Eclipta alba (L.) Hassk.	NA	Yerba de Tago
Erigeron modestus Gray	NP	Plains Fleabane
Eupatorium greggia Gray	NP	Palmleaf Eupatorium
Gymnosperma glutinosum (Spreng.) Less	NP	Tatalencho
Helenium quadridentatum Labill.	NA	Rosilla
Helianthus annuus L.	NA	Common Sunflower
Helianthus ciliaris DC.	NP	Blue-Weed
Heterotheca fulcrata (Greene) Shinners	NP	Rocky Goldaster
Hymenoclea monogyra T. & G.	NP	Burro-Bush
Ivy ambrosiaefolia Gray	NA	Rag Sumpweed
**Machaeranthera gypsophila* B. L. Turner	NP	
Machaeranthera scabrella (Greene) Shinners	NP	
Machaeranthera wrightii (Gray) Cronq. & Keck	NP	
Melampodium leucanthum T. & G. var. *leucanthum*	NP	Plains Blackfoot
Parthenium confertum H.B.K.	NP	Lyreleaf Parthenium
Parthenium incanum H.B.K.	NP	Mariola
Pectis papposa Harv. & Gray	NA	Many-Bristle Pectis
Perityle parryi Gray	NP	Heartleaf Perityle
Perityle vaseyi Coult.	NP	
Porophyllum scoparium Gray	NP	
Senecio douglasii DC. var. *jamesii* (T. & G.) Ediger	NP	Threadleaf Groundsel
Solidago altissima L.	NP	Tall Goldenrod
Sonchus asper (L.) Hill	IA	Prickly Sowthistle
Stephanomeria pauciflora (Torr.) A. Nels.	NP	Desert Skeltonplant
Trixis californica Kellogg	NP	American Trixis
Verbesina encelioides (Cav.) Gray	NP	Cowpen Daisy
Viguiera dentata (Cav.) Spreng.	NP	Sunflower Goldeneye
Viguiera stenoloba Blake	NP	Resin-Bush
Xanthium strumarium L.	NA	American Cocklebur, Abrojo
Xanthocephalum microcephalum (DC) Shinners	NP	Snakeweed
Zexmenia brevifolia Gray	NP	Shorthorn Zexmenia

APPENDUM TO THE COLORADO CANYON VEGETATION SURVEY A SEASONAL COMPARISON

Mary Butterwick and Jim Lamb

Information included in this appendum was based on field studies carried out on October 3 and October 4, 1975. The purpose of the fall survey was to observe and record any seasonal changes as a means of comparison with the data gathered the previous summer. Since most of the annual precipitation in this region occurs in August and September, particular attention was paid to possible effects of rainfall on the different plant associations. This task was accomplished through incidental collecting, with emphasis on species not found during the summer. In addition, each of the established transect sites was revisited and fall data were obtained (see section on Methods). The transect sites were accurately relocated. However, the positioning of the 100-m tape was impossible to duplicate. Because of the inherent variability of this sampling technique, the transect data frequently showed a slightly different composition of the grass, herb, and shrub components from that seen in the summer transect data. Although exact comparisons were not feasible, general trends did present themselves and will be elaborated on in the following discussion.

THE SLOPE ASSOCIATION

Significant changes were observed within the Slope Association of the Colorado Canyon, apparently as a result of recent substantial rains. Values for Total Raw Coverage increased from 45.35% to 61.5% at one transect site and from 46.51% to 56.9% at the other site. Similarly, the grasses increased in both ground cover and diversity. Total Raw Coverage values of 24.16% and 30.82% showed noticeable increases over summer values of 19.1% and 20.11% respectively. The presence of *Aristida adscensionis, Trichachne californica, Bouteloua barbata,* and *Tridens muticus* accounted for the higher diversity in the grass composition. *Gymnosperma glutinosum* and *Xanthocephalum microcephalum,* both primarily fall-flowering Compositae, frequented the slopes of Colorado Canyon. Aside from the above instances, little significant change was observed in the shrubs and herbs of this association. A majority of the species involved were perennials and thus would not be expected to fluctuate markedly in frequency or relative dominance with the seasons.

THE ALLUVIAL-GRAVEL ASSOCIATION

The Alluvial-Gravel Association was consistent in the predominance of shrubs such as *Larrea tridentata* and *Acacia neovernicosa* and the scarcity of grasses which accounted for only 6.94% of the total coverage (Table 3). *Jatropha dioica* and *Bahia pedata* remained as dominant herbs. However, the fall transect showed an increase in the diversity of herbaceous species, including the frequently occurring *Hibiscus denudatus, Pectis papposa,* and *Sida filicaulis.* This variance in the species diversity is more a result of the sampling methods used rather than seasonal fluctuations in the presence of these perennial species.

THE RIPARIAN ASSOCIATION

The Riparian Association was not evaluated quantitatively. However, its characteristic components, such as *Chilopsis linearis, Fallugia paradoxa, Hymenoclea monogyra, Acacia greggii,* and *Prosopis glandulosa,* being trees or shrubs, do not vary noticeably with the seasons. The infrequent herbaceous species scattered along the banks of the drainages reflect those that were found on the slopes and alluvial gravels.

FALL TRANSECT DATA

TABLE 1
Quadrat Transect 12

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	10	20	7.81	23.21	68	2.66	4.32	133
Aristida ternipes	21	42	16.40	13.65	40	8.50	13.82	425
Bouteloua barbata	1	2	0.78	0.68	2	0.20	0.32	10
Bouteloua ramosa	18	36	14.06	13.31	39	12.10	19.67	605
Erioneuron pulchellum	1	2	0.78	2.39	7	0.70	1.14	35
HERBS								
Agave lecheguilla	19	38	14.84	15.70	46	18.40	29.92	920
Allionia incarnata	1	2	0.78	0.68	2	0.40	0.65	20
Argythamnia neomexicana	4	8	3.12	1.36	4	0.50	0.81	25
Bahia absinthifolia	5	10	3.90	1.71	5	1.44	2.34	72
Boerhaavia coccinea	1	2	0.78	0.34	1	0.10	0.16	5
Brickellia coulteri	1	2	0.78	0.34	1	0.40	0.65	20
Carlowrightia arizonica	2	4	1.56	0.68	2	0.30	0.49	15
Echinocereus sp.	1	2	0.78	0.34	1	0.30	0.49	15
Euphorbia arizonica	2	4	1.56	0.68	2	0.50	0.81	25
Euphorbia cyathophora	5	10	3.90	1.71	5	0.80	1.30	40
Jatropha dioica	19	38	14.84	15.70	46	7.90	12.85	395
Machaeranthera scabrella	1	2	0.78	1.02	3	0.40	0.65	20
Rhynchosia texana	3	6	2.34	1.02	3	0.50	0.81	25
Sarcostemma cynanchoides	1	2	0.78	0.34	1	0.10	0.16	5
Viguiera dentata	6	12	4.69	3.07	9	2.50	4.06	125
SHRUBS								
Opuntia phaeacantha	2	4	1.56	0.68	2	0.70	1.14	35
Opuntia rufida	2	4	1.56	0.68	2	0.90	1.46	45
Trixis californica	1	2	0.78	0.34	1	0.20	0.32	10
Yucca torreyi	1	2	0.78	0.34	1	1.00	1.63	50
TOTALS	128		99.94%	99.97%	293	61.50%	99.97%	3075%

FALL TRANSECT DATA

TABLE 2
Quadrat Transect 13

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	3	6	2.40	8.67	17	1.40	2.45	70
Bouteloua ramosa	39	78	31.20	37.24	73	26.32	46.09	1316
Erioneuron pulchellum	1	2	0.80	0.51	1	0.10	0.18	5
Pappophorum mucronulatum	1	2	0.80	0.51	1	0.10	0.18	5
Setaria leucopila	3	6	2.40	1.53	3	0.60	1.05	30
Trichachne californica	1	2	0.80	1.02	2	1.00	1.75	50
Tridens muticus	6	12	4.80	4.08	8	1.30	2.28	65
HERBS								
Agave lecheguilla	1	2	0.80	0.51	1	.30	0.53	15
Bahia absinthifolia	10	20	8.00	9.18	18	1.34	2.35	67
Cassia bauhinioides	1	2	0.80	0.51	1	0.10	0.18	5
Dyssodia pentachaeta	1	2	0.80	1.02	2	0.20	0.35	10
Echinocereus sp.	1	2	0.80	0.51	1	0.10	0.18	5
Hedeoma drummondii	2	4	1.60	1.02	2	0.20	0.35	10
Jatropha dioica	3	6	2.40	2.04	4	0.44	0.77	22
Machaeranthera gypsophila	9	18	7.20	7.65	15	2.54	4.45	127
Machaeranthera scabrella	6	12	4.80	4.59	9	1.30	2.28	65
Menodora decemfida	10	20	8.00	6.63	13	4.70	8.23	235
Mentzelia oligosperma	1	2	0.80	0.51	1	0.10	0.18	5
Parthenium confertum	1	2	0.80	0.51	1	0.10	0.18	5
Perityle vaseyi	1	2	0.80	0.51	1	0.20	0.35	10
Ruellia parryi	4	8	3.20	2.04	4	1.70	2.98	85
Selaginella lepidophylla	1	2	0.80	0.51	1	0.10	0.53	15
Selinocarpus angustifolius	1	2	0.80	0.51	1	0.10	0.18	5
SHRUBS & TREES								
Coldenia greggii	5	10	4.00	1.53	3	2.06	3.61	103
Ephedra aspera	1	2	0.80	0.51	1	0.80	1.40	40
Fouquieria splendens	2	4	1.60	1.02	2	1.90	3.33	95
Koeberlinia spinosa	1	2	0.80	0.51	1	1.76	1.75	50
Larrea tridentata	5	10	4.00	2.55	5	5.20	9.11	260
Opuntia leptocaulis	1	2	0.80	0.51	1	0.20	0.35	10
Opuntia phaeacantha	1	2	0.80	0.51	1	0.30	0.53	15
Prosopis glandulosa	1	2	0.80	0.51	1	0.80	1.40	40
Xanthocephalum microcephalum	1	2	0.80	0.51	1	0.30	0.53	15
TOTALS	**125**		**100.00%**	**99.97%**	**196**	**56.90%**	**100.06%**	**2855%**

FALL TRANSECT DATA

TABLE 3
Quadrat Transect 14

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	3	5.00	1.79	2.29	7	0.50	1.02	30
Aristida ternipes	1	1.67	0.59	0.33	1	0.08	0.17	5
Bouteloua barbata	4	6.00	2.38	2.94	9	1.35	2.77	81
Bouteloua ramosa	3	5.00	1.79	0.98	3	3.42	7.00	205
Erioneuron pulchellum	11	18.33	6.55	5.23	16	1.48	3.04	89
Panicum sp.	1	1.67	0.59	0.33	1	0.08	0.17	5
Tridens muticus	1	1.67	0.59	0.33	1	0.03	0.07	2
HERBS								
Agave lecheguilla	1	1.67	0.59	0.65	2	0.08	0.17	5
Allionia choisya	1	1.67	0.59	0.33	1	0.03	0.07	2
Argythamnia neomexicana	6	10.00	3.57	1.96	6	0.52	1.06	31
Bahia absinthifolia	7	11.67	4.17	2.94	9	1.00	2.05	60
Bahia pedata	29	48.33	17.26	18.95	58	7.05	14.45	423
Baileya multiradiata	3	5.00	1.79	0.98	3	0.33	0.68	20
Boerhaavia coccinea	9	15.00	5.36	2.94	9	1.22	2.49	73
Cassia bauhinioides	6	10.00	3.57	6.53	20	0.63	1.30	38
Croton pottsii	1	1.67	0.59	0.33	1	0.33	0.68	20
Euphorbia simulans	10	16.67	5.95	10.13	31	0.88	1.81	53
Hibiscus denudatus	3	5.00	1.79	0.98	3	4.00	8.20	240
Iva ambrosiifolia	1	1.67	0.59	0.33	1	0.08	0.17	5
Jatropha dioica	7	11.67	4.17	3.92	12	2.50	5.12	150
Machaeranthera scabrella	1	1.67	0.59	0.33	1	0.02	0.03	1
Nerisyrenia camporum	1	1.67	0.59	0.33	1	0.08	0.17	5
Pectis papposa	17	28.33	10.12	18.63	57	0.38	6.93	203
Sida filicaulis	12	20.00	7.14	4.90	15	0.83	1.71	50
Thamnosma texana	4	6.00	2.38	3.59	11	0.27	0.55	16
Tidestromia lanuginosa	1	1.67	0.59	0.33	1	0.17	0.34	10
SHRUBS								
Acacia neovernicosa	6	10.00	3.57	1.96	6	5.67	11.62	340
Fouquieria splendens	4	6.00	2.38	1.31	4	3.83	7.86	230
Larrea tridentata	11	18.33	6.55	4.25	13	7.08	14.52	425
Lycium berlandieri	1	1.67	0.59	0.33	1	1.50	3.07	90
Opuntia leptocaulis	1	1.67	0.59	0.33	1	0.17	0.34	10
Opuntia violacea	1	1.67	0.59	0.33	1	0.17	0.34	10
TOTALS	**168**		**99.95%**	**100.02%**	**306**	**48.76%**	**99.97%**	**2927%**

APPENDUM TO COLORADO CANYON SPECIES LIST

A — Annual
P — Perennial
I — Introduced
N — Native
* — Endemic or Rare

POACEAE		GRASS FAMILY
Aristida adscensionis L.	NA	Six Weeks Three Awn
Bouteloua aristidoides (H.B.K.) Grieseb.	NA	Needle Grama
Enneapogon desvauxii Beauv.	NP	Spike Pappus Grass
Panicum sp.		
EUPHORBIACEAE		SPURGE FAMILY
Euphorbia arizonica Engelm.	NP	
Euphorbia cyathophora Murr.	NA	
Euphorbia exstipulata Engelm.		
MALVACEAE		MALLOW FAMILY
Sida filicaulis T. & G.	NP	Spreading Sida
STERCULIACEAE		CACAO FAMILY
Ayenia filiformis Wats.	NP	
OLEACEAE		OLIVE FAMILY
Menodora decemfida (Gill) Gray var. *longifolia* Steyerm.	NP	Tenfinger Menodora
CONVOLVULACEAE		MORNING GLORY FAMILY
Ipomoea costellata Torr.	NA	Morning Glory
VERBENACEAE		VERVAIN FAMILY
Tetraclea coulteri Gray	NP	
ACANTHACEAE		ACANTHUS FAMILY
Ruellia parryi Gray	NP	

RANGES AND RANGE MANAGEMENT IN THE COLORADO CANYON AREA, PRESIDIO COUNTY, TEXAS

C. Wayne Hanselka

Traditionally, there has been but a single use of much of the land in the Trans-Pecos region of Texas: the husbandry of domestic livestock. An ever-increasing population, however, has placed greater demands on land use for traditional products, such as food and fiber, as well as for areas for recreation and for esthetic values. In view of these increasing demands, land use is being reevaluated, and the means are being sought to integrate multiple uses into a single harmonious system.

Rangelands in the Big Bend area are no exception. Historically, these ranges have been utilized exclusively for ranching. Since the middle and late nineteenth century and the settlement of the Indian problem, inhabitants of the area have grazed their stock on the extensive grasslands, mountains, and desert bolsons of this area.

In the mid-1950's the sale of hunting rights became popular, so that today recreational hunting has become a major industry. Tourism has been growing at the same time. Areas for camping, hiking, sightseeing, etc., are being demanded, as more and more people travel to Big Bend National Park only to find there is not enough room.

Solution of these problems and the full integration of these land uses may be accomplished by proper planning and management. It is my opinion that this can be accomplished if emotionalism is ignored and priorities are set, based on the capabilities of the land. A sound basis for this is the art and science of range management. This discipline employs ecological knowledge of rangelands for the protection, improvement, and continued welfare of the range resource with optimum production of goods and services as needed by society. The central objective is to provide forage for domestic and wild animals.

The material that follows describes the ranges and possible management practices in the area including and surrounding the Colorado Canyon on the Rio Grande in southwest Texas.

THE STUDY AREA

Colorado (Spanish: red) Canyon is a canyon on the Rio Grande approximately 60 km downriver from Presidio in Presidio County, Texas. It is associated with the Bofecillos Mountains to the north and the Sierra Rica to the south in Mexico.

The area is of igneous origin with soils in the Brewster Stony-Rough Mountainous series. The topography is mountainous, cut by several deep canyons. Numerous washes drain the area to the south and empty into the Rio Grande, the principal drainage. The river is the only permanent water source, with the possible exception of several springs that flow for short distances in the larger canyons. Flash floods are a hazard when rain falls on the northern portions of the area.

The climate is semiarid with less than 203 mm of precipitation received annually. This usually falls in the late summer and autumn months. Temperature ranges are extreme with temperatures above 40°C not uncommon in the summer. Nights are cool. Freezing temperatures do occur during the winter but usually are of short duration.

Vegetation is typical of the Chihuahuan desert. The area is classified as a desert shrub grassland. Creosotebush (*Larrea divaricata*), Lechuguilla (*Agave lechuguilla*), Ocotillo (*Fonqueria splendens*), and Mesquite (*Prosopsis juliflora*) are the shrubs that dominate the understory of xeric grasses and ephemeral forbs.

The area under consideration encompasses approximately 12,000 hectares (30,000 acres).

RESULTS AND DISCUSSION

Range Sites

One of the basic concepts of range management is that all land in an area is not equal. Land units can be classified as various combinations of ecological factors such as topography, soils, slope, etc., resulting in varying abilities to produce vegetation. Such a unit is termed a range site. There are three range sites in The Colorado Canyon area: igneous hills and mountains, gravel, and draw.

Igneous hill and mountain sites: The Bofecillos Mountains, of which the area is a part, are of igneous origin. Weathering and erosion on moderately steep to steep slopes have resulted in sites with shallow soils associated with fragments of igneous rocks and boulders. Short and mid-grasses associated with xeric-adapted shrubs dominate the climax community. Shrubs invade or increase with over-use, drought, and/or other forms of retrogression. Perennial and ephemeral forbs are numerous after precipitation is received. This igneous hill and mountain site occupies about 70% of the area.

Gravel sites: Low areas between the higher mesas, peaks, and hills have over the eons slowly been filled with a gravel detritus as a result of normal geologic processes. Gravel sites cover 25% of the area and occupy terrain ranging from gently rolling to hills and ridges of 3-8% slope. Soils are generally shallow, gravelly loams with associated stones up to 7.5 cm (3 in) in size. Climax vegetation is sparse short-grasses with an abundance of shrubs. Shrubs increase with a decrease in grasses.

Draw sites: As is true in most areas of uneven terrain and sparse ground cover, erosion has cut numerous draws and creeks to allow drainage from surrounding upland areas. These drainages, except for short distances below perennial springs, flow only intermittently. Slope varies from nearly level to level. Soils are usually deep and alluvial in origin. They are rich with a good soil-air-moisture-plant relationship. The draw sites are subject to severe flash flooding and overgrazing. Consequently, the productive short and midgrasses of the climax community are usually replaced by a dense growth of shrubs. This site occupies approximately 5% of the study area.

Range Condition

There are several methods of determining the condition of a range. In this survey, condition is based upon the percentage of climax plant species now present as compared to the percentage that is present at climax. Overgrazing, drouth, fire, or some other means of vegetation removal results in retrogression to a lower successional community. This results in a lowered amount of palatable, nutritious, productive vegetation (usually grasses). A concurrent increase in less desirable plant species occurs. These are called increasers and provide good forage for livestock. The aim of management is to retain a good mixture of "increaser" and "decreaser" species.

Continued retrogression removes the good forage species and allows replacement by "invader" species. These are generally shrubby and annual plant species that provide little forage for livestock. A vegetation cover of all "invader" species is also of little use to wildlife.

The plant species in each of the decreaser, increaser, and invader classes may behave differently on different range sites.

Condition classes are based upon:

- Excellent: 76-100% climax species in the composition
- Good: 51-75% climax species in the composition
- Fair: 26-50% climax species in the composition
- Poor: 0-25% climax species in the composition

Species composition on each range site was determined by line intercept methods and compared to climax vegetation descriptions provided by the Soil Conservation Service. Stocking rates were estimated from tables prepared by the SCS.

The igneous mountain site occupies 8422 hectares within the confines of the study area. The site was determined to be in fair condition with 36.2% of the present vegetation being climax species. Chino grama (*Bouteloua breviseta*) and two Muhlys (*Muhlenbergia sp.*) are the dominant grasses. Lechuguilla (*Agave lecheguilla*) is the prominant invader shrub. Numerous annual and perennial herbaceous forbs are also present. The latter are transient, however, and provide forage only for short periods during the year, generally following precipitation.

Carrying capacity for this site, in fair condition, is 42.8-85.2 hectares/animal units/year long. An animal unit is based upon the forage needed by a mature cow or her equivalent.

The gravel site occupies 2406 hectares in the area and is in low fair condition. Vegetation is sparse with few desirable grass species present (3%). Woody shrubs contribute 14% and forbs contribute 10% of the total climax composition of the 27% present. In this condition 128 hectares/animal unit is needed for yearlong grazing.

The draw site is also in low fair condition. This site includes areas along the Rio Grande and portions of Rancherias Canyon, Panther Canyon, and Madera County (601 hectares).

In its present condition the carrying capacity of this site is 42 hectares/animal unit/year.

Range Management and Improvement

Management of rangeland is predicated upon the concepts of site and range condition. Several principles may then be followed to maintain or improve the range. The primary consideration is that of proper use. Livestock numbers must be balanced with forage available without detrimental effects to the vegetation. Stocking then is an important first step in proper management.

Since livestock tend to go the easy way, it is logical that certain areas will be utilized more than other areas. Flat, easily accessible sites will be used first and heaviest with very little use made of rough, broken areas. This behavioral trait can be overcome with judicious use of improvements such as fencing, water, and mineral supplements.

The Colorado Canyon area is in overall fair condition. The area has a carrying capacity of 186 animal units based upon the vegetation. Unless proper distribution is achieved, however, this estimate is meaningless. The only fence observed was one near the mouth of Madera Canyon. The rugged terrain provides many natural barriers that preclude the moving of cattle. Over much of the range water is lacking in both quantity and supply. The main water source is the Rio Grande with secondary sources, principally of springs and troughs, at widely scattered localities. In the mountains, water should be available to cattle at ½-to-1 km intervals. This is usually impossible to attain, but the distance between water should not exceed 2 km.

Until such improvements are applied, the carrying capacity of the area will remain low and the vegetation will remain in a static or retrogressing condition.

VERTEBRATE FAUNA OF THE COLORADO CANYON AREA, PRESIDIO COUNTY, TEXAS

James F. Scudday

The biota of geographical borders is always of interest to biologists, especially if the border represents an international boundary, for it is in such border areas that a nation may record rare and peripheral species as a part of its native fauna. If the boundary consists of a river that traverses many different ecological gradients, it is of even greater interest. Such rivers, during their existence, have served as barriers to the dispersal of some species and thoroughfares for the dispersal of others. In deserts, species adapted to mesic habitats may occur as isolates in river valleys surrounded by inhospitable terrain.

Colorado Canyon and the area associated with it represent such a border area of great biological interest. The physiography and the geographic location obviously tie the area more to the Mexican Highlands than to the rest of the United States. Only an ancient fact of river meanderings has placed the area in the U.S. at all. There are indications that the river has allowed some forms of life to be sustained here that could not exist otherwise, while also serving to introduce life forms into the area from other regions.

Bats and birds particularly are able to use the river corridor as a throughfare through an otherwise inhospitable and unlikely terrain. As would be expected, the bat and bird fauna along the Rio Grande and its tributaries are some of the most diverse found anywhere.

The Rio Grande of southeastern Presidio County is an important consideration in interpreting the fauna of the Colorado Canyon area. The river is historically a part of two rivers, and the place of origin of these two rivers has had a direct influence on the biota. The Conchos River, originating in the Sierra Madre Occidental, cut across desert plains and through arid mountains as it flowed northward from Mexico. The Rio Grande, originating in the high, cool Rockies of Colorado, flowed southward, eventually turning southeastward at El Paso del Norte. The two rivers met at La Junta, just above the present town of Presidio. From here the combined flow of these two mighty rivers cut and channeled through the rugged Big Bend country.

Early surveyors considered the Rio Grande to be the main stream, with the Conchos only a tributary. Historic records for 19 years before any dams show that 70% of the water comes from the Conchos. The Rio Grande from El Paso to Presidio now is a dry wash except for brief periods of heavy rainfall when run-off water may flow down its channel for several days at a time. That flowing segment we call the Rio Grande from Presidio to the mouth of the Pecos River is in reality nothing more than the lower Conchos River. Agricultural demands made along the length of the Rio Grande have expropriated almost its last drop of water before it exits El Paso County. Similar demands now being made upon the waters of the Conchos in Mexico could soon bring about the same fate for that river. It could be a matter of only a few years until there is no longer a flowing river through the canyons of the Big Bend country.

The deep, rugged canyons of the Rio Grande and its drainages between Lajitas and Redford were long isolated from most people, including scientists. Only occasional fishermen ventured onto the few, often deteriorating, jeep roads that led into the area. In the late 1950s it was decided to forge a paved Farm-to-Market Road parallel with the Rio Grande from Lajitas to Redford. This road, in spite of being paved, still constitutes a challenge to drivers, as it contains more curves, dips, and steeper grades than any other state road in Texas. Yet it has opened up one of the largest wilderness areas remaining in the United States to tourists who want to see the rugged grandeur of the Great Chihuahuan Desert in relative ease with just a hint of challenge.

The road, now known as the Camino del Rio, has made areas once accessible only to ranchhands and a few fishermen readily accessible to casual campers, sightseers, fishermen, and scientists. Since the completion of the highway in 1961, the road has become a popular tour for biologists and geologists from all over the nation. Biologists, in particular, have taken advantage of the highway and its uncontrolled access to the canyons and river to collect series of Chihuahuan Desert mammals and reptiles. Herpetologists and commercial snake hunters today drive thousands of miles to reach the area so they can drive the road after dark in hopes of collecting specimens of the region's many rare species of reptiles that crawl upon the pavement at night. It is not unusual to see commercial snake collectors with specially adapted vehicles—large spotlights mounted all around the vehicle and tractor seats mounted on the fender so a rider can quickly pounce upon anything spotted—cruising up and down the highway at intervals all night long. It is known that occasionally collectors are so numerous that they draw for starting positions to "run the road."

The Camino del Rio now attracts almost as many "snake hunters" as does the Langtry area and will probably soon exceed the Langtry area in popularity. There are legitimate scientific reasons for collecting reptiles from Texas highways, but the commercial exploitation of this wildlife resource should be controlled. I was approached by a young man driving a California-licensed van along the Camino del Rio during June, 1975, and I asked to look over his catch. He had four Trans-Pecos Rat Snakes for which he asked \$50 apiece. He informed me he could get from \$75 to \$100 apiece for them in California.

Because of the easy access to a once remote area and the recent rather intensive investigations of biologists along the Camino del Rio, good records are available of the fauna of the area. The highway represents a well-established transect along which a great amount of data has been collected.

Generally, the areas south of the highway to the Rio Grande, including Colorado Canyon, have been extensively worked by biologists, while the areas north of the highway have been relatively untouched. I have been conducting field investigations into the area since 1958. The Big Hill and Colorado Canyon areas have long been ideal for conducting biology department field trips for Sul Ross State University. Although many biological investigations have been made in the area, little has been published about the fauna. Only Olson's (1974) published study on the Canyon Lizard is available.

Sul Ross State University, University of Texas at El Paso, University of Arizona, and Texas A&M University have extensive holdings of vertebrates from the study area. I have made use of the collections at those institutions to supplement my data for this report.

The limits of the study area, as used in this report, are from the mouth of Madera Canyon westward to the mouth of Tapado Canyon and north along the 915-m contour of the Bofecillos Mountains. This includes the streambeds and drainages below 915 m of Rancherias, Tapado, Panther, and Madera Canyons. The Rio Grande is the southern boundary. Ranch Road 170 (Camino del Rio) parallels the Rio Grande through most of the area, swinging north and away from the river only at Colorado Canyon. Important named places included within the area are Big Hill, Closed Canyon, Colorado Canyon, the Teepees Roadside Park, and Rancherias Springs.

Numerous unnamed springs and seeps occur within the major canyons of the study area. These, together with the Rio Grande, provide an abundance of water available to wildlife. However, the severity of periodic flash floods in the narrow canyons has prevented the development of a truly riparian habitat along the lower ends of these drainages, such as that occasionally found in the higher parts of some of these same canyons. Even the seasonal fluctuations of the Rio Grande have prevented the stabilization of a truly riparian habitat along its course. The consequences of such periodic flooding must have a disastrous effect upon some terrestrial animal populations along the stream courses (Fig. 1).

The effects of human impact are obvious along the Rio Grande, but almost nil north of RR 170. Some areas along the river have served as favorite fishing camps for over 20 years, and the accumulation of litter is almost unbelievable. As far as I know, no effort has ever been made to control litter along this stretch of the river, and apparently few people have bothered to carry their litter out. To some extent, the litter has proved a bonanza for some small mammals, primarily rodents and skunks.

Most fisherman and many casual campers bring guns to their camps along the river. Beavers, hawks, vultures, snakes of all kinds, turtles, "varmints," and many small birds are often shot for sport or catfish bait. Cliff swallow nests are broken and robbed of baby birds for bait. Easy access to this segment of the Rio Grande for the past 14 years has engendered, through carelessness and neglect by human users, a genuine threat to the wild nature of its river canyons.

Following are lists of the species of vertebrates known to exist within the bounds of the study area. Species are listed by Class, with a discussion concerning pertinent details or special problems that exist for some species following each Class list. The occurrence of each species listed is usually validated by voucher specimens or reliable observations. Some species may be included on basis of known specimens from similar habitat nearby (less than three miles or five km), and a few rare species are listed with evidence and probability of their occurrence covered in the discussion following the Class list. Common names of amphibians and reptiles are those of Thomas (1974). Common names of birds are those of Wauer (1973) and those of mammals after Davis (1966).

FIGURE 1

A large sand spit at the mouth of a canyon on the Mexican side of the Rio Grande. This canyon is across and downriver from Closed Canyon on the Texas side. The canyon is easily followed through a mountain to a large creosote-bush flat. Such canyons probably serve as a means of dispersal and access to the river for lowland species.

THE AMPHIBIAN FAUNA OF THE COLORADO CANYON AREA

CLASS AMPHIBIA

Order Caudata	
Family Ambystomatidae	*Ambystoma tigrinum*—Barred Tiger Salamander
Order Anura	
Family Pelobatidae	*Scaphiopus couchi*—Couch's Spadefoot
Family Hylidae	*Hyla arenicolor*—Canyon Treefrog
Family Bufonidae	*Bufo punctatus*—Red-spotted Toad
	Bufo speciosus—Texas Toad
	Bufo woodhousei—Woodhouse's Toad
Family Michrohylidae	*Gastrophryne olivacea*—Great Plains Narrow-mouthed Toad
Family Ranidae	*Rana berlandieri*—Rio Grande Leopard Frog

DISCUSSION

In spite of the presence of the Rio Grande, the kinds of amphibians found in the Colorado Canyon area are no different from those found throughout the more arid regions of southern Presidio County. The Rio Grande Leopard Frog is the only amphibian that resides and reproduces in the river itself. All other forms of amphibians of the area are ephemeral and depend upon seasonal rainfall filling temporary pools for successful reproduction. Cricket Frogs (*Acris crepitans*) may have occurred here in the Rio Grande at one time. Strecker (1909) and Netting and Goin (1946) recorded the species from several localities in western Brewster County, but it no longer occurs there either (Scudday 1976).

Predaceous fish in the Rio Grande probably are a factor in limiting the kinds of amphibians that can successfully colonize the river. At least one species, the Barred Tiger Salamander (*Ambystoma tigrinum*), is recorded from the area as a result of individuals brought to the river by fishermen as fish bait. The "water dog," particularly its larval stage, is especially preferred by fishermen going after the Yellow Catfish. Leftover bait is either dumped into the river or into some nearby stock pond or small spring, perhaps in hopes that the salamander will become established, resulting in a new source for bait, I have on occasion seen a number of Tiger Salamanders in the Rock House Spring near Lajitas and in stock ponds near Redford.

The only amphibian recorded from the Colorado Canyon area not found in the Fresno Canyon area was the Great Plains Narrow-mouthed Toad. Yet this amphibian was collected from a temporary pool in the creosote desert, and its presence is not associated with the Rio Grande. The high pitched trill of the tiny Narrow-mouth Toad was heard at night in a number of localities between Redford and Lajitas.

Couch's Spadefoot, Red-spotted Toads, and the Texas Toad are the most commonly encountered amphibians along Ranch Road 170. These toads are abundant in the vicinity of Colorado Canyon during the summer months following moderate to heavy rainfall. July and August are the months of heaviest rainfall in the area and the best months for observing amphibian activity.

The Canyon Tree-frog occurs in most of the steep-walled canyons of the Rio Grande and its drainages in the Bofecillos Mountains. Specimens have been taken from Colorado Canyon, Closed Canyon, Panther Canyon, and near the spring in lower Rancherias Canyon.

REPTILIAN FAUNA OF THE COLORADO CANYON AREA

CLASS REPTILIA

Order Chelonia—Turtles	
Family Kinosternidae	*Kinosternon hirtipes*—Mexican Mud Turtle
	K. flavescens—Yellow Mud Turtle
Family Emydidae	*Chrysemys scripta gaigeae*—Big Bend Turtle
Family Trionychidae	*Trionyx spiniferus*—Spiny Softshell
Order Squamata	
Suborder Lacertilia	
Family Geokonidae	*Coleonyx brevis*—Texas Banded Gecko
	C. reticulatus—Big Bend Gecko
Family Iguanidae	*Cophosaurus texanus*—Greater Earless Lizard
	Crotaphytus collaris—Collared Lizard
	Phrynosoma modestum—Round-tailed Horned Lizard
	Sceloporus magister—Twin-spotted Spiny Lizard
	S. merriami—Canyon Lizard
	S. undulatus—Fence Lizard
	Uta stansburiana—Side-blotched Lizard
	Urosarus ornatus—Tree Lizard
Family Scincidae	*Eumeces obsoletus*—Great Plains Skink
	E. brevilineatus—Short-lined Skink
Family Teiidae	*Cnemidophorus septemvittatus*—Rusty-rumped Whiptail
	C. tesselatus E—Checkered Whiptail
	C. tigris—Western Whiptail
Suborder Serpentes	
Family Leototyphlopidae	*Leptotyphlops dulcis*—Texas Blind Snake
Family Colubridae	*Arizona elegans*—Glossy Snake
	Elaphe guttata emoryi—Emory's Rat Snake
	E. subocularis—Trans-Pecos Rat Snake
	Ficimia cana—Western Hook-nosed Snake
	Hypsiglena torquata—Night Snake
	Lampropeltis mexicana—Gray-banded Kingsnake
	Masticophis flagellum—Coachwhip
	M. taeniatus—Striped Whipsnake
	Rhinocheilus lecontei—Texas Long-nosed Snake
	Salvadora hexalepis—Big Bend Patch-nosed Snake
	Sonora semiannulata—Trans-Pecos Ground Snake
	Tantilla atriceps—Mexican Black-headed Snake
	Thamnophis eyrtopsis—Mexican Black-necked Garter Snake
	Trimorphodon villkinsoni—Texas Lyre Snake
Family Viperidae	*Agkistrodon contortrix pictogaster*—Trans-Pecos Copperhead
	Crotalus atrox—Western Diamondback Rattlesnake
	C. lepidus—Rock Rattlesnake
	C. molossus—Black-tailed Rattlesnake
	C. scutulatus—Mojave Rattlesnake

Reptiles possible, but no records of:

Holbrookia maculata
Phrynosoma cornutum
Cnemidophorus inornatus
Diadophis punctatus
Elaphe obsoleta bairdi
Heterodon nasicus
Salvadora grahamiae
Tantilla nigriceps
T. rubra cucullata
Thamnophis marcianus
Pituophis melanoleucus

DISCUSSION

As mentioned in the introduction, good records of the reptilian fauna of the Colorado Canyon–Lajitas area are available. The occurrence of four species of turtles, three of them river forms, is possible only because of the Rio Grande. Two of these, the Mexican Mud Turtle and the Big Bend Turtle, are forms with limited distribution.

Thomas (1974) treated the Big Bend Turtle as a species (*Chrysemys gaigeae*), while Conant (1975) considered it a subspecies of the Pond Slider (*Chrysemys scripta gaigeae*). A river form, this taxon is found only in the Big Bend portion of the Rio Grande, the Conchos River in Mexico, and a small portion of the Rio Grande in southern New Mexico (Conant 1975).

The Mexican Mud Turtle has even a more limited U.S. distribution, being recorded only from southern Presidio County. This species ranges southward in Mexico to Zacatecas (Conant 1975). It has been found more often in farm ponds than in the river. The Yellow Mud Turtle is primarily a pond turtle and is widely distributed in Texas.

The Spiny Softshell is strictly a river form, being found along the length of the Pecos River and the flowing portion of the Rio Grande.

Two unusual lizards occur within the study area. These are the Canyon Lizard and the Big Bend Gecko. Big Bend Geckos are extremely rare and are known only from southwestern Brewster and southeastern Presidio Counties. The species is tentatively included on a list of reptiles to be protected by Texas state law. Few specimens are known from the study area, and the upper end of Colorado Canyon probably represents the westernmost edge of the species' distributional limits. Presently, no specimens are known from west of Big Hill.

Systematics of the various populations of the Canyon Lizard were studied by Olson (1974). He concluded that the population of Canyon Lizards in Presidio County represented a distinct subspecies of the taxon, whereupon he named the population *Sceloporus merriami longipunctatus*. Olson designated Closed Canyon as the type locality for the subspecies. Conant (1975) referred to this subspecies by the trivial name of Presidio Canyon Lizard. Olson's report establishes an important type locality within the study area.

Most of the lizards of the study area are typical Chihuahuan species. However, some interesting problems exist.

Imagine a line drawn from the Davis Mountains to Colorado Canyon. Samples of *Sceloporus* populations taken along that line would show the Spiny Crevice Lizard was common in the Davis Mountains but that Canyon Lizards did not occur there. Proceeding southward along that line, specimens of the Canyon Lizard and of the Spiny Crevice Lizard would be about equally common at San Jacinto Mountain. At the Solitario and Fresno Canyon area, Canyon Lizards would predominate with very few Spiny Crevice Lizards in the sample. At the southern terminus of the line at Colorado Canyon, only Canyon Lizards would be found (Fig. 2). Competitive factors that allow the small Canyon Lizard to replace the large Spiny Crevice Lizard in this part of their range needs to be investigated.

Within Colorado Canyon itself, fluctuating water levels must pose a constant threat to all kinds of terrestrial vertebrates, particularly those kinds that are not adept at climbing (Fig. 3). Investigations within the canyon revealed that two species of lizards generally not considered climbing forms could be found along narrow strips of sand between the river bank and the vertical canyon walls. The two lizards were the Side-blotched Lizard and the Checkered Whiptail. These two species apparently recolonize flood-zone areas almost immediately after the water recedes.

In many instances, these two kinds of lizards were found on isolated strips of bank that could be reached only by descending vertical cliffs. Is this the way the lizards recolonize flood zones, or are they actually able to escape the effect of flooding by burrowing or scampering up the cliffs and above danger?

Side-blotched Lizards were almost always seen on the sand near boulders or at the base of the cliffs. When pursued, they readily scampered up the cliffs or over the boulders. Checkered Whiptails however were never seen escaping into the rocks. Instead, they sought escape among flood debris or in the willow thickets at the water's edge.

The interesting aspects of the inter-relationships of the three species of whiptails (*Cnemidophorus*) found in the study area were discussed in some detail in the companion volume on Fresno Canyon (see Scudday, Fresno Canyon Area TNAS Report). Checkered Whiptails and Western Whiptails are found sympatrically throughout most of the study area. The Rusty-rumped Whiptail was found only occasionally and always right at the northern edge of the study area where the highlands of the Bofecillos Mountains drain into the major canyons of the Rio Grande flood plains. Small isolated populations of this species may occur on some of the higher mountain tops, such as Santana Mesa and the unnamed mountain bordering Colorado Canyon on the north. Cursory investigations of these areas were inconclusive.

Of the two species of skinks, the Great Plains Skink prefers the mesquite lowlands, while the

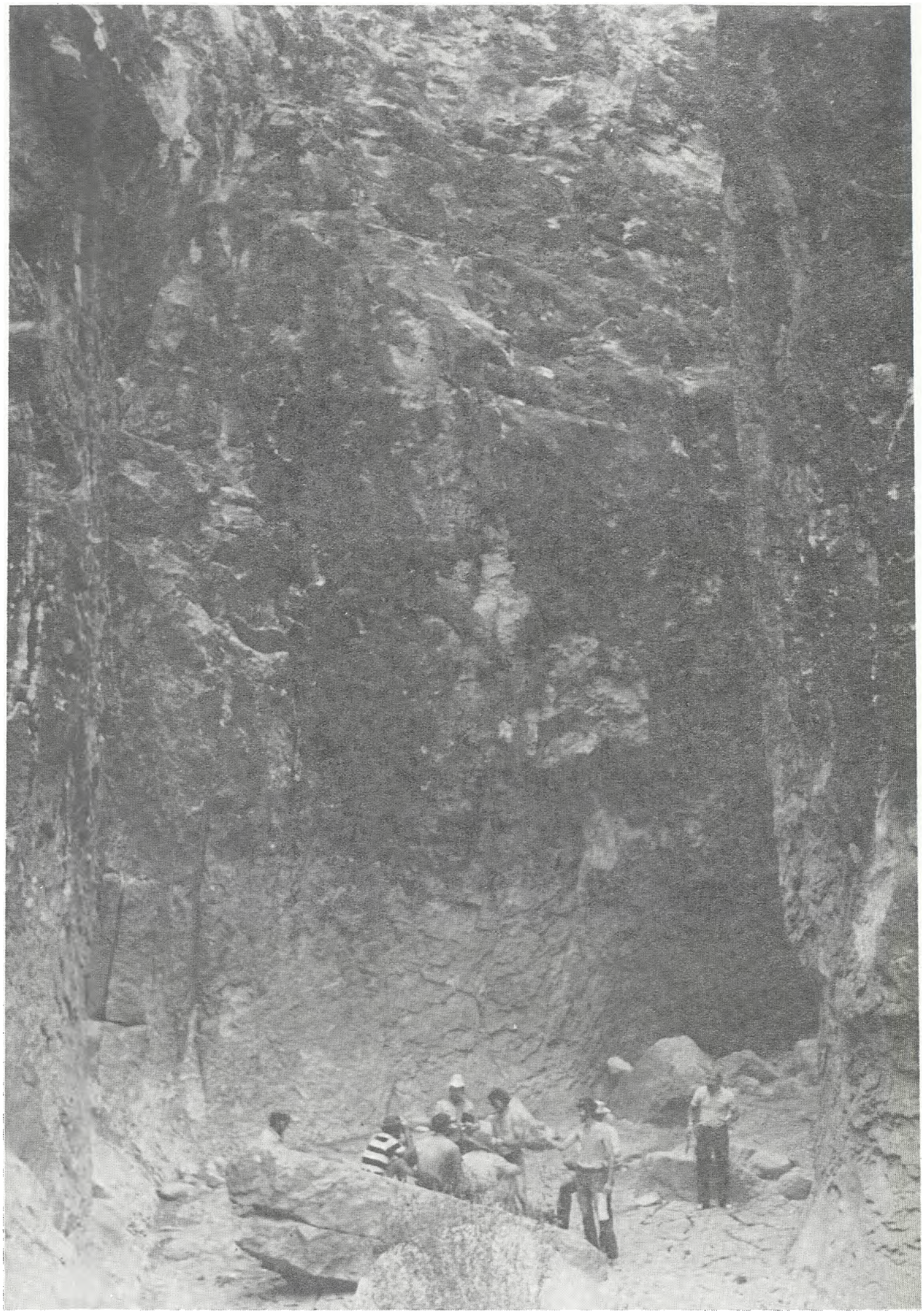

FIGURE 2

Just inside the mouth of the canyon in Fig. 1.
Canyon Lizards (*Sceloporus merriami*) occupy steep canyon walls.
Note the high water mark.

FIGURE 3

The lower end of Closed Canyon with the Rio Grande in the foreground.
Note the scoured effect of high water right up to the base of the cliff.
Checkered Whiptails (*Cnemidophorus tesselatus*) and Side-blotched Lizards (*Uta Stansburiana*) occur in these flood zones.

Short-lined Skink is usually found along the canyon slopes. A Short-lined Skink was taken on the hillside at the mouth of Colorado Canyon.

Snakes represent the largest and most diverse of the herpetofauna of the study area. Twenty species of snakes are documented from the area, while an additional eight species probably occur there but have not been documented. Of the 20 documented forms, one-fourth (five species) are venomous.

The Glossy Snake is a common species along the sandy washes of the creosote bush desert between the Bofecillos Mountains and Presidio, but usually it is not found within the rocky canyon country between the Bofecillos Mountains and the Rio Grande. The species barely occurs in the study area. A Sul Ross specimen is from the old rock house ruins near the mouth of Tapado Canyon. University of Texas at Permian Basin has a specimen from "3.4 mi. W. Lajitas."

Three snake species occurring in the area are considered rare or endemic to Trans-Pecos Texas. Two of these, the Gray-banded Kingsnake and the Trans-Pecos Rat Snake, are included on a list of reptiles protected from general collecting by the State of Texas. The third one, the Texas Lyre Snake, is actually the rarest species of all but is not included on the state list. All three of these species have been recorded from Big Hill.

Actually, the Trans-Pecos Rat Snake is one of the more common snakes of the area but probably will not be for long because of the presistent pressure of commercial collectors. Although the state has issued a list of amphibians and reptiles protected from general collecting, no enforcement of the prohibition was undertaken in 1975-1976. Ranch Road 170 is heavily worked during the spring and summer months by commercial collectors.

Venomous forms are represented by four species of rattlesnakes and a copperhead. Of these, the Western Diamondback Rattlesnake is the most common. Rock Rattlesnakes and Trans-Pecos Copperheads are the least common and are much sought by some commercial collectors. Trans-Pecos Copperheads were once very common at Rock House Springs but are seldom found there now.

THE AVIFAUNA OF COLORADO CANYON

Authentic bird records for the study area are sketchy, although the avifauna has probably been observed more than any other vertebrate component. I have kept some records since 1963. I have relied heavily upon observations by Roland Wauer and confirmed some such records with him during an interview in January, 1976. Grainger Hunt has generously shared his observations of raptors with me. Birders from all over the U.S. have taken trips through Colorado Canyon, and, if all existing records could be compiled, the following list perhaps would be doubled. I suspect that the actual list of birds that might be seen within a year's time in the study area would come close to including all the birds listed in Wauer's (1974) *Birds of Big Bend National Park and Vicinity*.

The following compilation is broken down into four categories. Birds that are found in the summer months of June, July, and August are designated (S). Many of these birds nest in the area. Birds found there during December through February are designated (W). Migrant birds (M) occur during the months of March through May, and September through November. The symbol (Y) designates species that can be found in the area all year, and definitely nest in the area.

		S	W	M	Y
CLASS AVES					
Order Podicipediformes					
Family Podicipedidae					
	Pied-billed Grebe			X	
Order Ciconiiformes					
Family Ardeidae					
	Great Blue Heron		X	X	
	Green Heron		X	X	
	Snowy Egret			X	
	Louisiana Heron			X	
	American Bittern			X	

Order Anseriformes					
Family Anatidae					
	Mallard		X	X	
	Mexican Duck				X
	Gadwall		X	X	
	Pintail		X	X	
	Green-winged Teal		X	X	
	Blue-winged Teal		X	X	
	Cinnamon Teal		X	X	
	American Widgeon (Baldpate)		X	X	
	Shoveler		X	X	
	Wood Duck			X	
	Red Head		X	X	
	Ring-necked Duck		X	X	
	Lesser Scaup			X	
	Bufflehead			X	
	Ruddy Duck			X	
	Common Merganser			X	
Order Falconiformes					
Family Cathartidae					
	Turkey Vulture	X		X	
	Black Vulture			X	
Family Accipitridae					
	Cooper's Hawk		X		
	Sharp-shinned Hawk		X	X	
	Red-tailed Hawk				X
	Swainson's Hawk	X		X	
	Golden Eagle		X	X	
	Marsh Hawk			X	
Family Falconidae					
	Sparrow Hawk				X
	Prairie Falcon				X
Order Galliformes					
Family Phasianidae					
	Scaled Quail				X
	Gambel's Quail				X
Order Gruiformes					
Family Rallidae					
	Virginia Rail			X	
	Sora Rail		X	X	
	Coot				X
Order Charadriiformes					
Family Charadriidae					
	Killdeer				X
Family Scolopacidae					
	Common Snipe		X	X	
	Spotted Sandpiper		X	X	
	Solitary Sandpiper			X	
	Greater Yellowlegs			X	
	Baird's Sandpiper		X	X	
	Least Sandpiper		X	X	
	Western Sandpiper		X	X	

Order Columbiformes					
Family Columbidae					
	White-winged Dove				X
	Mourning Dove				X
	Ground Dove	X		X	
	Inca Dove	X		X	
Order Cuculiformes					
Family Cuculidae					
	Yellow-billed Cuckoo	X			
	Road Runner				X
Order Strigiformes					
Family Strigidae					
	Screech Owl				X
	Great Horned Owl				X
	Elf Owl	X		X	
Order Caprimulgiformes					
Family Caprimulgidae					
	Poor Will				X
	Common Nighthawk			X	
	Lesser Nighthawk	X		X	
Order Apodiformes					
Family Apodidae					
	White-throated Swift	X		X	
Family Trochilidae					
	Lucifer Hummingbird	X		X	
	Black-chinned Hummingbird	X		X	
	Anna's Hummingbird	X		X	
	Broad-tailed Hummingbird	X		X	
	Rufous Hummingbird			X	
	Blue-throated Hummingbird			X	
Order Coraciiformes					
Family Alcedinidae					
	Belted Kingfisher			X	
Order Piciformes					
Family Picidae					
	Red-shafted Flicker				X
	Yellow-bellied Sapsucker			X	
	Ladder-backed Woodpecker	X		X	
Order Passeriformes					
Family Tyrannidae					
	Western Kingbird	X		X	
	Ash-throated Flycatcher	X		X	
	Eastern Phoebe		X		
	Black Phoebe				X
	Say's Phoebe				X
	Empidonax spp.			X	
	Olive-sided Flycatcher			X	
	Vermilion Flycatcher				X

Family Hirundinidae					
	Bank Swallow			X	
	Rough-winged Swallow	X		X	
	Barn Swallow	X		X	
	Cliff Swallow	X			
Family Corvidae					
	Common Raven	X		X	
	White-necked Raven			X	
Family Paridae					
	Verdin				X
Family Troglodytidae					
	House Wren		X	X	
	Cactus Wren				X
	Canyon Wren				X
	Rock Wren				X
Family Mimidae					
	Mockingbird				X
	Curvebill Thrasher				X
	Brown Thrasher		X		
	Crissal Thrasher				X
	Sage Thrasher			X	
Family Turdidae					
	Robin		X	X	
	Hermit Thrush		X	X	
Family Sylvidae					
	Blue-gray Gnatcatcher			X	
	Black-tailed Gnatcatcher				X
	Ruby-crowned Kinglet		X	X	
Family Motacillidae					
	Water Pipit		X	X	
Family Bombycillidae					
	Cedar Waxwings		X	X	
Family Ptilogonatidae					
	Phainopepla			X	
Family Lanidae					
	Loggerhead Shrike				X
Family Vireonidae					
	Bell's Vireo	X		X	
Family Parulidae					
	Orange-crowned Warbler		X	X	
	Nashville Warbler			X	
	Parula Warbler			X	
	Yellow Warbler	X		X	
	Audubon's Warbler		X	X	
	Black-throated Gray Warbler				X
	Northern Waterthrush			X	
	MacGillivray's Warbler			X	
	Yellow Throat	X		X	
	Yellowbreasted Chat	X		X	
	Wilson's Warbler			X	
Family Icteridae					
	Western Meadow Lark		X	X	
	Yellow-headed Blackbird		X	X	
	Red-wing Blackbird			X	
	Orchard Oriole	X			

	Scotts Oriole	X		X	
	Bullocks Oriole	X		X	
	Brewers Blackbird		X	X	
	Brown-headed Cowbird				X
Family Thraupidae					
	Summer Tanager	X		X	
Family Fringillidae					
	Cardinal		X	X	
	Phrrhuloxia				X
	Blue Grosbeak	X		X	
	Varied Bunting	X		X	
	House Finch				X
	Pine Siskin		X	X	
	Painted Bunting	X		X	
	Green-tailed Towhee		X	X	
	Brown Towhee				X
	Lark Bunting		X	X	
	Grasshopper Sparrow		X	X	
	Vesper Sparrow		X	X	
	Lark Sparrow			X	
	Black-throated Sparrow				X
	Dark-eyed Junco		X	X	
	Chipping Sparrow		X	X	
	Clay-colored Sparrow		X	X	
	Brewers Sparrow		X	X	
	White-crowned Sparrow		X	X	
	Lincoln's Sparrow		X	X	
	Song Sparrow		X	X	

DISCUSSION

The Rio Grande's permanent supply of a large volume of water has created a habitat completely unlike the vast Chihuahuan Desert through which it flows. The river provides a mesic corridor and refugium through which highly mobile animals can move and rest. Birds, being the most mobile of all animals, are able to exploit this environmental factor to the utmost. Numerous species of aquatic and wading birds can be found utilizing the river for resting, feeding, and, sometimes, nesting. The fall months of October and November are the months that most likely produce the greatest number of avian species along the river, but the spring months of April and May are good months for bird records, too.

Ducks and sparrows are more evident in the fall than in the spring, but warblers may be more numerous in the spring than in the fall. A leisure float trip down the river is the best way to see the most birds. Birds that are numerous one year may not even occur there the next. Wauer (1974) refers to "sparrow years" in the Big Bend National Park when many species are abundant, followed by years when certain species previously seen did not occur.

Grainger Hunt of the Chihuahuan Desert Research Institute conducted an extensive survey along the Rio Grande in search of Peregrine eyries or evidence of their presence. Although no Peregrines were found in the study area, he did locate a pair of Prairie Falcons nesting near the mouth of Closed Canyon. These falcons could be seen from Ranch Road 170 during most of 1975.

The presence of Gambel's Quail in the area is of interest. This desert species is rare this far east, and additional sightings need to be documented. Wauer (1974) states the species once occurred as far east as Big Bend National Park, but it is not known to be there now.

More species of owls than the three reported here probably periodically visit the study area. Wauer records 10 species of owls for Big Bend National Park, but most of those are montane species.

Hummingbirds are common along the Rio Grande and can be readily found in spring and early summer around the abundant tree tobacco plants. Wauer (1974) recorded 13 species of hummers in Big Bend National Park. Six are known from the Colorado Canyon Area. Keith Arnold and I found a Broad-tailed Hummingbird nesting in Closed Canyon in May, 1968.

Numerous warblers can be found as migrants passing along the river corridor in April and May. Most of the warbler species listed are from Ro Wauer's records. Specimens in the Sul Ross Collection from the area include the Orange-crowned Warbler, Nashville Warbler, Yellow-throat, Yellow-breasted Chat, and Audubon's Warbler. The Parula Warbler is included here on the basis of sight records at Lajitas on April 19, 1974, and near the Redford Dam on April 27, 1974. These sight records are from localities on each side of the study area. Wauer (1974) stated that the Parula Warbler has been increasing in numbers in the Big Bend National Park since 1967.

The Yellow-breasted Chat is the most visible of the warblers during the summer months. This large warbler can almost always be found in the dense willow thicket at the mouth of Colorado Canyon.

Sparrows, like the warblers, are common components of the area's migratory avifauna. However, while spring is the time to look for warblers, fall and early winter belongs to the sparrows. Only the Black-throated Sparrow is a year-round resident. During November or December, the swampy areas or weedy places along the river are the places to find many of the species.

MAMMALIAN FAUNA OF COLORADO CANYON AREA

CLASS MAMMALIA

Order Chiroptera		
	Family Mormoopidae	*Mormoops megalophylla*—Leaf-chinned Bat
	Family Vespertilionidae	*Pipistrellus hesperus*—Canyon Bat
		Plecotus townsendi—Lumpnosed Bat
		Antrozous pallidus—Pallid Bat
		Eptesicus fuscus—Brown Bat
		Myotis velifer—Cave Bat
		M. yumanensis—Yuma Bat
	Family Mollosidae	*Tadarida mexicana (=brasilensis)*—Mexican Freetailed Bat
		T. molossa—Big Freetailed Bat
		Eumops perotis—Western Mastif Bat
Order Lagomorpha		
	Family Leporidae	*Lepus californicus*—Jackrabbit
		Sylvilagus auduboni—Desert Cottontail
Order Rodentia		
	Family Sciuridae	*Spermophilus spilosoma*—Spotted Ground Squirrel
		S. varigatus—Rock Squirrel
		Ammospermophilus interpres—Texas Antelope Ground Squirrel
	Family Geomyidae	*Thomomys bottae*—Valley Pocket Gopher
	Family Heteromyidae	*Perognathus merriami*—Merriam's Pocket Mouse
		P. nelsoni—Spiny Pocket Mouse
		P. penicillatus—Desert Pocket Mouse
		Dipodomys merriami—Merriam's Kangaroo Rat
	Family Cricetidae	*Peromyscus boyli*—Brush Mouse
		P. pectoralis—Encinal Mouse-(White-ankled)
		Neotoma albigula—White-throated Woodrat
		Ondatra zibethicus—Muskrat
	Family Erethizontidae	*Erethizon dorsatum*—Porcupine
	Family Castoridae	*Castor canadensis mexicanus*—Mexican Beaver
Order Carnivora		
	Family Canidae	*Canis latrans*—Coyote
		Urocyon cinereoargenteus—Gray Fox
	Family Ursidae	*Ursus americanus*—Black Bear
	Family Procyonidae	*Procyon lotor*—Raccoon
		Bassariscus astutus—Ringtail Cat

Family Felidae	*Lynx rufus*—Bobcat
	Felis concolor—Mountain Lion
Family Mustelidae	*Taxidea taxus*—Badger
	Mephitis mephitis—Striped Skunk
	Spilogale gracilis—Spotted Skunk
	Conepatus mesoleucus—Nognosed Skunk
Order Artiodactyla	
Family tayassuidae	*Pecari (Tayassu) tajacu*—Javelina
Family Cervidae	*Odocoileus hemionus*—Mule Deer

DISCUSSION

Easterla (1973) recorded 18 species of bats from nearby Big Bend National Park. Only 10 species have been recorded from the Colorado Canyon study area; however, more than 10 species probably occur there. Many of the local bats water from the river, but bats are difficult to capture over large expanses of water such as the Rio Grande. Most of the species recorded here were either netted over small pools of water some distance from the river or shot while flying over the river and along its banks. Two species, the Brown Bat and the Yuma Bat, were taken from small openings or crevices in the limestone bluffs in Colorado Canyon.

Pallid Bats were the most abundant bats of the area in July. These bats could be found by the 100's in night roosts under bridges along Ranch Road 170, and were easily netted while foraging among the willows and tamarisks along the river banks.

Western Mastiff Bats were not captured at Colorado Canyon, but are included on basis of their presence in nearby Fresno Canyon and the visual sightings of large bats with loud voices foraging along the river late at night and early in the morning (between 11:30 p.m. and 3:00 a.m.). Easterla (1973) found that Mastiff Bats emerged late but foraged all night. He further stated that ideal roost habitat for the Western Mastiff Bat, as well as for the Pocketed Free-tailed Bat (*Tadarida femorosacca*), the Big Freetailed Bat (*Tadarida macrotis*), and the extremely rare Spotted Bat (*Euderma maculatum*), occurs in all the deeper canyons of the Rio Grande. Continued monitoring of the bat fauna within the study area will likely produce almost all the 18 species recorded from Big Bend National Park.

The occurrence of muskrats here in the Rio Grande is an interesting possibility. A review of the status of the Muskrat in Trans-Pecos Texas was given by K. Holmes (1970), and its taxonomic status was discussed by J. Holmes (1970). The race of Muskrat to be expected in the study area would be *Ondatra zibethicus ripensis*, the Pecos River Muskrat. According to K. Holmes, this race has been extirpated from nearly all its former range and is now limited to irrigation canals and drainage ditches in southeastern El Paso County. No specimens of Muskrat were taken or seen in Colorado Canyon, but I have had reports of Muskrats along stretches of the river from Rock House Spring (ca. three miles or five km. west of Lajitas) to within a few miles of Big Hill. These reports are from reliable sources, biologists who have seen plenty of muskrats in other areas. I have also heard of two Muskrat skins sold to a fur dealer in Presidio two years ago. On these bases I am including the Muskrat as a very likely possibility for the river fauna. The occurrence of Muskrats in this portion of the Rio Grande needs further authentication as it would represent a significant return of a species to its former range.

That Beavers occur in Colorado Canyon is without question. Almost anyone that floats the canyon is likely to see these large rodents in the water. Slides, holes in the banks, and evidence of their gnawing activity are evident almost everywhere the canyon walls do not come right to the water's edge.

Much is yet to be learned of the Mexican Beaver in the Rio Grande. These beavers do not build dams nor lodges as beavers elsewhere do. No one knows about their reproductive cycle or potential. Along the Rio Grande in Big Bend National Park, 30 years of protection has allowed the beaver to make a remarkable comeback—so much, in fact, they have become too successful. The presence of too many beavers at Rio Grande Village near Boquillas has posed a problem of excessive damage to shade trees. Some form of beaver control is warranted in situations where trees are of such value.

Unfortunately, in the Colorado Canyon area, beavers are presently considered fair game for anyone with a .22 rifle yearning for something at which to shoot. I have also seen Beavers caught by hooks on trout lines placed in the river for catfish. These Beavers are usually fouled in the webbing of the foot, not in the mouth, and I suspect they could care less for any of the baits on the hooks. It is not unusual to find a dead Beaver somewhere while floating the river. I'm sure the floods also take their toll. Beavers are truly one of the unique mammalian species of the Colorado Canyon area and should not be eradicated.

The ecological partitioning of habitats by mice of the genus *Peromyscus* presents an interesting problem. Brush mice and Encinal mice can often be captured in the same trap line in the Davis Mountains to the north. However, in the Colorado Canyon area, the Brush Mouse was confined to the more mesic habitats along the river's edge (Fig. 4) while the Encinal Mouse occupied more xeric habitats of the mountain sides and creosote bush desert (Fig. 5). Only Brush mice were captured within the confines of Colorado Canyon. Here they were trapped on the rocky slopes as well as the narrow sandy beaches. Yet this species has not spread beyond the river corridor, even up some of the larger tributaries. The Brush Mouse was not found in Fresno nor Chorro Canyon, both very mesic areas. The Brush Mouse probably represents a more mesic-adapted species of *Peromyscus* that has been able to use the Rio Grande as a corridor to extend its range deep into the more arid portions of the Chihuahuan Desert. Perhaps harsh, xeric conditions magnify the adaptive differences of these two species in this area thereby limiting each to a preferred habitat, while in some other areas the climate is more ameliorated, deemphasizing adaptive differences and permitting co-existence of the two species within the same habitat.

Carnivores are not generally numerous along this stretch of the Rio Grande. This, too, is primarily because easy access to this part of the river results in heavy human impact and indiscriminate use of guns. "Varmint calling" has long been practiced by fishermen, campers, and hunters in the immediate vicinity. Skunks are the only carnivores commonly encountered, and these animals have apparently benefited by man's presence. Skunks are attracted to camps along the river, where they feed on garbage left behind and enjoy the protection of their reputation. Even the most trigger-happy camper doesn't want to risk having to move camp by shooting a skunk.

Of the four species of skunks in Trans-Pecos Texas (Patton 1972) only the Hooded Skunk (*Mephitis macroura*) has not been reported from the study area. Patton (personal communication) believes the species probably occurs in limited numbers in southern Presidio County, but it may be excluded because of climate and competitive factors.

Large carnivores such as Mountain Lions, Bobcats, and Coyotes are more often found around the less accessible northern edge of the study area (Fig. 6). Tracks of these predators can be found in the soft sand of streambeds and around waterholes throughout the Bofecillos Mountains. A Bobcat was seen crossing the road near the Teepees on the night of July 5, 1975.

Bears have been essentially extirpated from the area, although they once occurred there rather commonly. Even now a bear may suddenly appear along the river, only to disappear back into the neighboring mountains of Mexico. Tracks of bear are more likely to be encountered than the animal itself. That bears once did roam the Bofecillos Mountains is now testified to in the name of Oso Mountain.

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FIGURE 4

Colorado Canyon. Hardy mesquites grow luxuriantly at the base of the cliffs, but cottonwoods and large willows are generally absent within the canyon. The Brush Mouse (*Peromyscus boyli*) was found in the mesquite zone. The mesquites also provide habitat for migrant and nesting birds. Mexico to the left.

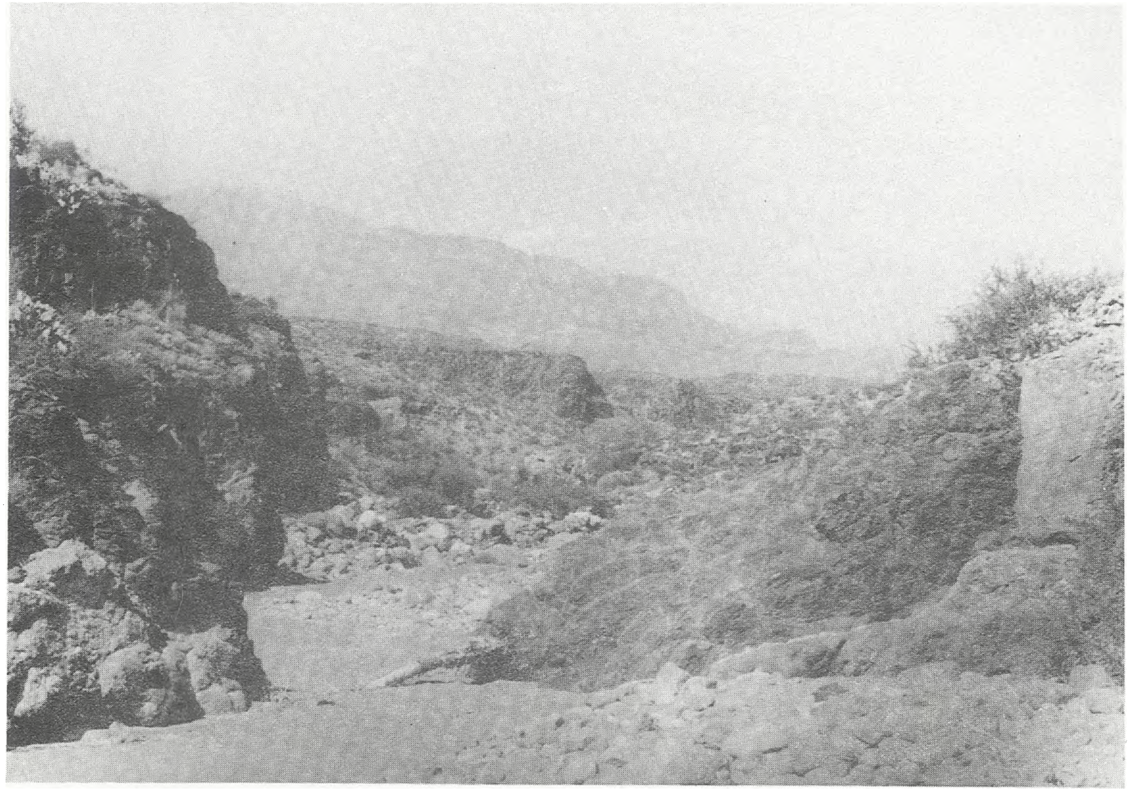


FIGURE 5

A typical dry wash about one-half mile north of the Rio Grande.
Encinal mice (*Peromyscus pectoralis*), Desert Pocketmice (*Perognathus penicillatus*), and
Lesser Nighthawks are common vertebrates in such areas. Bofecillos Mountains in the background.

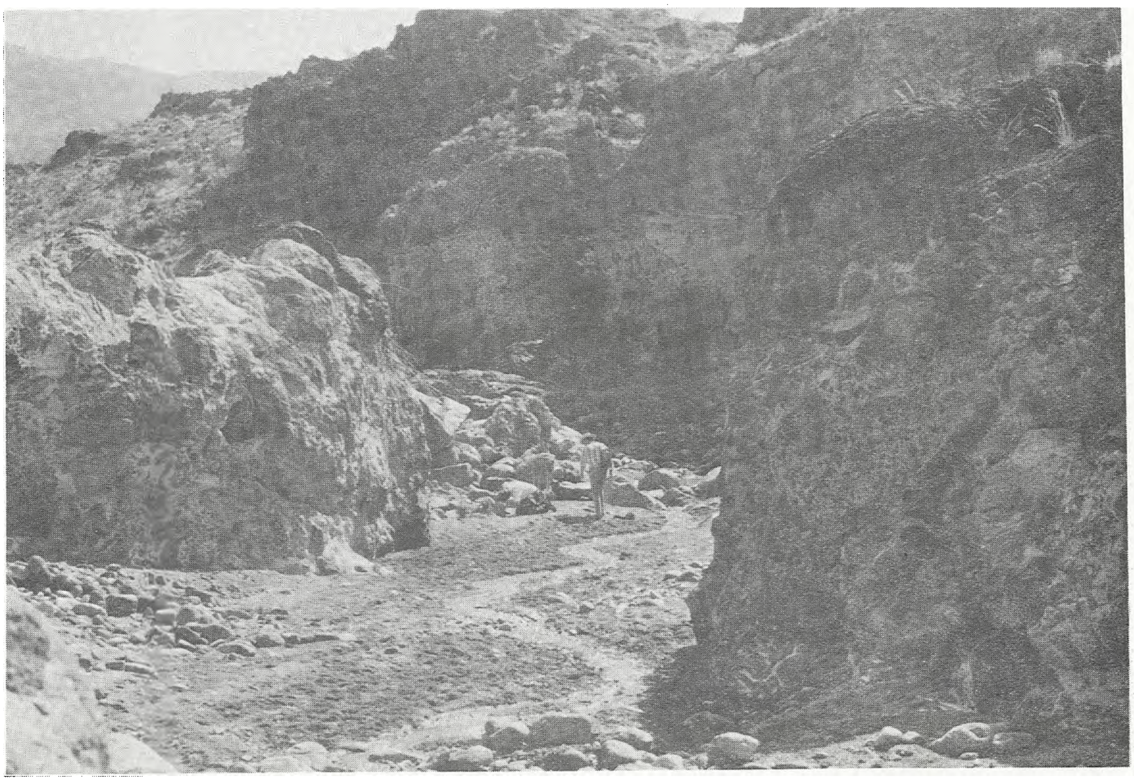


FIGURE 6

Lower Rancherias Canyon. Fresh running water in some of the canyons miles from the Rio Grande is an important resource. Large mammalian species can thus exist in areas not impinged upon too greatly by the large numbers of people attracted to the nearby Rio Grande.

ARCHEOLOGICAL RECONNAISSANCE OF COLORADO CANYON AREA

Barbara J. Baskin

INTRODUCTION

This report describes and evaluates 30 archeological sites located in the Colorado Canyon area of southern Presidio County, Texas. The area, owned by the Diamond A Cattle Company, borders the Rio Grande to the south and extends into the rugged Bofecillos Mountains to the north. From the sample of sites recorded by this brief preliminary study we can better understand man's relationship to this seemingly hostile land and further appreciate his adaptive capabilities in both the past and the present.

Negative impact on our resources by today's mobile population is constantly evidenced by the partial or total destruction of archeological sites. As important nonrenewable resources, these sites must be preserved and protected for future research. Survey reconnaissance and recording is vital in order that an inventory of the sites be made before they are destroyed or disturbed to an extent that renders them useless for scientific study.

The archeological field reconnaissance was performed by Michael G. Mallouf and Barbara J. Baskin. Other members of the multidisciplinary team who accompanied and aided in the research included: Mary Butterwick, botanist; Wayne Hanselka, range and wildlife management specialists, and Dwight Deal, geologist.

SURVEY TECHNIQUES

Prior to field reconnaissance, research of the general Colorado Canyon area was conducted with emphasis on searching the archeological records at the Texas Archeological Research Laboratory in Austin, Texas, for previously recorded sites in the specified area. Site 41PS125, located in April of 1975 by Tunnell and Mallouf (1975), and 41PS114, recorded in 1961 by L. D. Jones, were revisited and recorded and have been incorporated into the present report. The remaining sites, although some are known to local collectors, had never been recorded and/or evaluated.

An attempt was made to prepare a feasible research design which would yield the greatest amount of information concerning human utilization of various ecological niches within the bounds of the study area, while taking into consideration the strict time limitations placed on the project. Previous systematic archeological surveys conducted in surrounding areas which might serve as models for this survey were studied. The reconnaissance of Big Bend National Park (Campbell 1970) and the Davis Mountains (Marmaduke and Whitsett 1975) aided in the formulation of a research design for investigation of the rugged upland mountain and canyon areas. The Talley Ranch survey in Hudspeth County, Texas (Lynn and Baskin 1975) served as a model for archeological reconnaissance along the Rio Grande, its floodplain, and the north-south colluvial/alluvial gravel ridges which extend from the base of the Bofecillos Mountains to the Rio Grande floodplain. Specific areas for sampling were designated on the topographic maps with the expectation of some revision while in the field.

After witnessing the true ruggedness of the terrain and the natural barriers formed by the mountains and steep canyons, it was obvious that some of the areas specified for surveying in the original research design were inaccessible to us. It was also evident that investigation of additional areas along the Rio Grande above or below our designated survey boundaries for pottery-bearing sites would not be possible. After revision, the final research design included two major topographical areas, the Rio Grande area and the major tributary canyons, and a third division of arbitrary sample areas including the north-south extending gravel ridges, mesa tops, and other "spot-check" locations which appeared to be likely occupational or functional locales. It was hoped that from these areas we would obtain a representative sample of site type variability and a better understanding of site locations in relation to water resources, plant communities, lithic resource areas, and general topographic features.

Field reconnaissance was conducted on foot by two persons over an 11-day period. Use of Highway 170 and rough jeep trails facilitated access into some of the sample areas. Computerized survey forms were employed along with sketch maps, photographs, and the plotting of sites onto U.S.G.S. 7.5-minute quadrangle maps as a standardized method of recording. No subsurface testing or surface collections were undertaken. Artifacts were photographed and described in the field and then left on the surface of the site for controlled collection during future intensive work. Some flakes were collected as samples for lithic material type identification. Lithic samples from gravel bars in the Rio Grande within Colorado Canyon were also collected for identification and comparative purposes.

The 30 archeological sites were given permanent site designation numbers using the trinomial system—41 (Texas), PS (Presidio County), number (Xth recorded site in that county)—in accordance with the central data center at the Texas Archeological Research Laboratory, Balcones Research Center, Austin, Texas. In addition to the designated sites, six lithic scatter areas, two isolated bedrock metates, and a site on the Mexican side of the river were observed.

While in the field, interviews with local residents aided in the location of locally known sites. We were able to relocate site 41PS123 and to photograph artifacts recovered from the shelter when it was first discovered in 1931 by Simon Moreno. The H. C. Madrid family was of great assistance in this endeavor.

All field notes, photographs, field maps, and sketch maps are available for research purposes at the Texas Archeological Research Laboratory and Texas Historical Commission, Austin.

PHYSIOGRAPHY

The Colorado Canyon Survey area is located in the southern Bofecillos Mountains area and along the Rio Grande in the southeastern portion of Presidio County, Texas, bounded to the northwest by the rolling Redford Bolson and to the east by Madera Canyon (Fig. 1). The vast majority of the survey area lies in the mountains and dissected uplands which are now used solely for ranching and seasonal leasing to hunters. There is no farming within the boundaries of the survey area because the Rio Grande does not provide a sufficient floodplain in this vicinity as it does immediately to the northwest in the Redford Bolson.

Included within the Basin and Range physiographic province, four physiographic divisions can be designated (McKnight 1970:29-31): (1) high, rugged mountains eroded from volcanic rocks; (2) a fault-block zone with great relief characterized by steep cliffs and canyon walls; (3) breached bolsons containing gravel pediment surfaces of moderate relief, and (4) the Rio Grande Valley of relatively low elevation and little local relief.

The Bofecillos Mountains area contains a "Tertiary volcanic vent and a varied sequence of lava flows, tuff [welded, ed.], ash-flow tuff, and associated conglomerate, sandstone, and mudrock" (McKnight 1970:2). Of the lithics observed during the survey, the majority are of volcanic origin, and all are obtainable from local sources in the Bofecillos Mountains or from gravel sources located along the Rio Grande.

The areas of exposed tuff are important from an archeological standpoint because they often form rock shelters conducive to occupation, and sandstones associated with them can form good aquifers. Volcanism during Tertiary time, followed by block faulting and later dissection by the Rio Grande and its tributaries, has created the areas of high mountains, the discontinuous ridges dissected by large canyons, and the eroded gravel plains near the Rio Grande which are dissected by smaller arroyos. This rugged topography, as it relates directly to the archeology, restricts the number of habitable occupation areas. The mountains and gravel plains end abruptly at the Rio Grande where it cuts through the resistant Santana Tuff to flow through Colorado Canyon (McKnight 1970:31). In adjacent areas to the northwest and southeast of the canyon, the Rio Grande cuts into less resistant bolson deposits. Many portions of the river bank are steep with a limited number of high, flat terraces. Seasonal flooding of lower terraces is evidenced by alluvial deposition, erosional cuts, and high water marks from recent (1974) flooding.

The area is considered to be semiarid to arid with an average annual rainfall of approximately 208 mm and mean annual temperature of 40°C. The majority of the rains come in mid to late summer and early autumn. Torrential rains with accompanying flash flooding are not uncommon during summer months. Constant water is supplied by the Rio Grande and its major tributaries, with arroyos flowing only after heavy rains. Good aquifers, adequate to supply springs throughout the canyon areas (McKnight 1970:34), are common (see the geological report).

ARCHEOLOGICAL BACKGROUND

A brief summary of the cultural traditions of the southeastern Trans Pecos region as evidenced through the archeological record is presented for background reference. Included are a review of the stages of man's cultural development and a listing of previous archeological work conducted in adjacent areas. For further intensive discussion of the cultural sequences mentioned below, refer to the following: Kelley 1952; Schackleford 1955; Kelley, Campbell, and Lehmer 1940; Lehmer 1960; Campbell 1970; Marmaduke and Whitsett 1975; Story 1966.

The Bofecillos Mountains area, including the Colo-

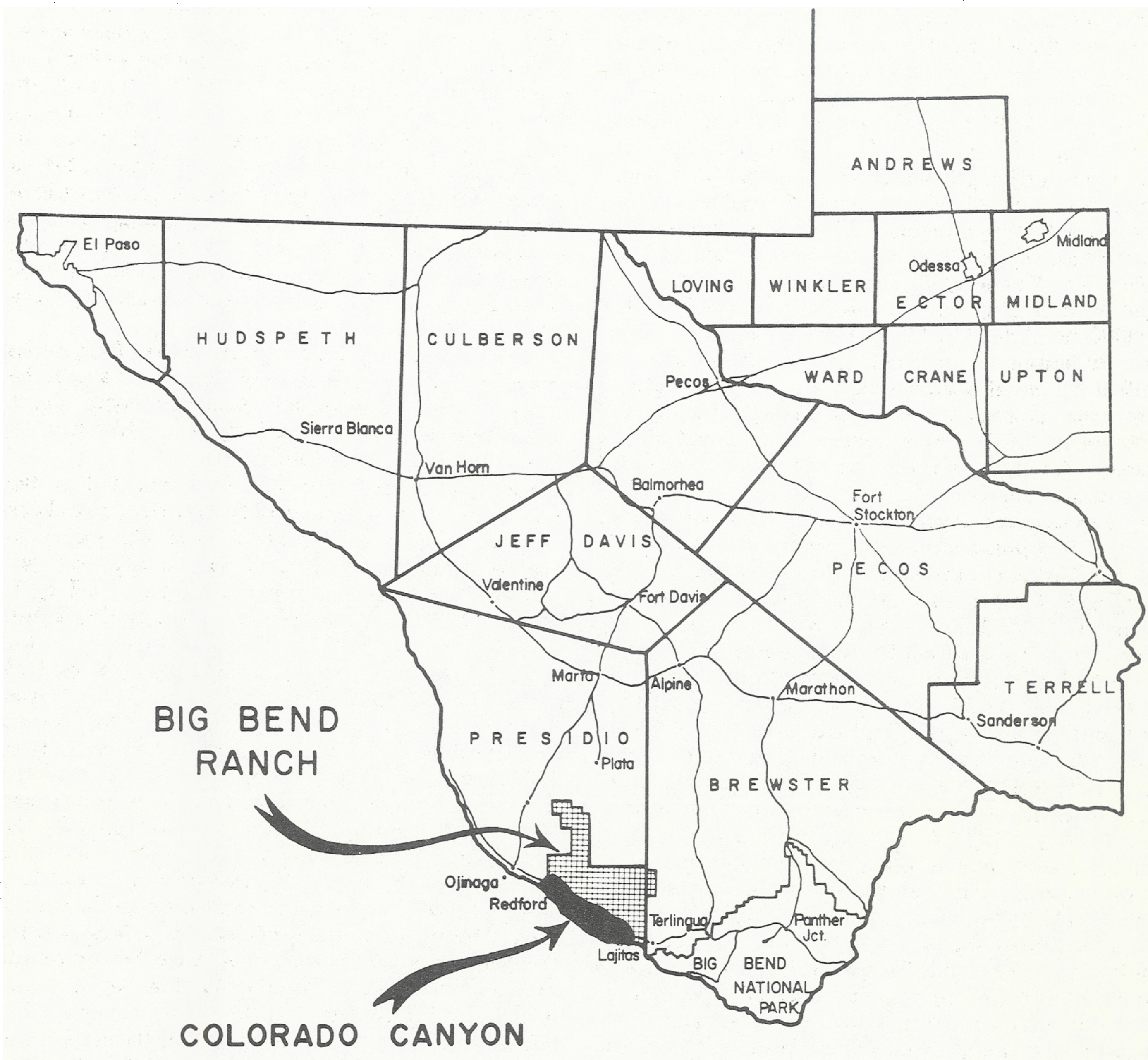

El Paso
HUDSPETH
CULBERSON
LOVING
WINKLER
ANDREWS
Odessa
Midland
ECTOR
MIDLAND
Pecos
WARD
CRANE
UPTON
Sierra Blanca
Van Horn
Balmorhea
Fort Stockton
JEFF DAVIS
Valentine
Fort Davis
PECOS
Marfa
Alpine
Marathon
TERRELL
Sanderson
PRESIDIO
Plata
BREWSTER
BIG BEND RANCH
Ojinaga
Redford
Terlingua
Panther Jct.
Lajitas
BIG BEND NATIONAL PARK
COLORADO CANYON

FIGURE 1

rado Canyon survey area, is an archeological void between two better understood areas where more intensive work has been done. The La Junta area (the region around the confluence of the Rio Grande and Rio Conchos) and Big Bend National Park have been subject to intermittent archeological work since the 1920s and cultural manifestations and an accepted chronology have been defined for this general portion of the Trans Pecos. The presently accepted names for the cultural units were assigned by Kelley, Campbell, and Lehmer (1940) as a revision of E. B. Sayles' (1935) original framework. Story (1966) recognized eight time-culture periods in the Amistad area and, because of the relative regional homogeneity, this chronology has been extended for use in the general Trans Pecos region (Marmaduke and Whitsett 1975).

Very few Paleo-Indian components have been located in the region, but the Archaic stage (B.C. 4000 or 5000 to A.D. 500-1000) has left abundant evidence of human occupation. The Archaic lifestyle is typified by small socio-cultural groups whose main subsistence is based on nonspecialized, seasonal exploitation of local flora and fauna. Since mobility is a necessity for this hunting and gathering economy, occupational camps are constructed on a temporary basis with seasonal reutilization. The Archaic stage in this area is represented by the poorly known Maravillas and Santiago cultures and the well-defined Pecos River and Chisos foci of the Big Bend aspect (Campbell 1970:22). The Pecos River focus is represented by cultural debris found in shelters and open sites, with an economy based primarily on wild plant gathering and, to a lesser degree, on hunting. As the last manifestation of the Big Bend aspect, the Chisos focus still relied on hunting and gathering for economic subsistence, but the impact of ceramic-making agriculturalists was felt during the latter part of the focus (Kelley 1952:276). Chisos focus materials have been located in shelters, open sites, and middens.

Contemporaneous with the late Chisos focus is an intrusive Plains-oriented cultural tradition known as the Livermore focus (A.D. 900-1300) (Lehmer 1960:120). Unlike the Pecos River and Chisos foci, peoples of the Livermore focus relied on an economy based primarily on hunting, with wild plant gathering of secondary importance. Open sites and shelters were utilized as occupational areas. The Livermore focus influenced the development of the lithic tradition of the later La Junta focus of the Bravo Valley aspect (Kelley 1952:276) and may also represent the first introduction of the bow and arrow in the southeastern Trans Pecos (Lehmer 1960:125).

The Neo-American stage (A.D. 500-1000 to A.D. 1500) of development arose with the increased dispersal and acceptance of agricultural techniques and ceramic manufacture, thus changing previous subsistence and settlement patterns. It should be remembered, however, that not all peoples accepted this change and made the transition from the Archaic lifestyle.

Influenced by the southward spread of sedentary, ceramic-manufacturing agriculturalists from the El Paso region, the Bravo Valley aspect developed as the first phase of a specialized local culture in and around the La Junta region (Kelley 1952:277). The La Junta focus (A.D. 1200-1400) is the first cultural unit of this manifestation. Represented by pithouses on terrace areas and shelters in volcanic tuff areas, the La Junta peoples increased their dependence on agriculture, while wild plant gathering and hunting became a secondary means of support. Ceramics, bowl and trough metates, and Perdiz projectile points, a style evidenced in the Livermore culture, are also representative of this focus.

The Concepcion focus (A.D. 1400-1700) varies from the La Junta focus only in ceramic and architectural styles, while the Conchos focus (A.D. 1700-1800+) is represented by the utilization of Spanish and European trade goods.

Previous archeological surveys conducted in the area are very limited, and only two sites have been partially excavated by professionals. The survey of Big Bend National Park, Brewster County, was performed during the summers of 1966 and 1967 by T. N. Campbell under the auspices of the National Park Service (Campbell 1970) as a continuation of the earlier surveys of 1936-1937 by Erik K. Reed (MS 1936) and 1937 by Paul R. Cook. A total of 628 sites has been recorded in the park, but no further testing or excavation has been conducted. During December, 1973, and July, 1974, lands to be affected by the rechannelization of the Rio Grande near Ojinaga, Mexico, and Presidio, Texas, were investigated by the Texas Archeological Survey for the National Park Service (Holliday and Ivey 1974). Marmaduke and Whitsett (1975) investigated some areas in the central Davis Mountains to the north of this survey area for the University of Texas Natural Areas Survey during the summer of 1974. Another brief survey was conducted by Liz Anderson of the Texas General Land Office in Chorro Canyon in 1973 (General Land Office Environmental Planning 1973). Another University of Texas Natural Areas Survey project was performed in the Solitario and Fresno Canyon during June, 1975, by Bill Hudson (1976). The present reconnaissance of the Colorado Canyon area completes the list of surveys thus far conducted in southeastern Presidio and Brewster counties. The Polvo site (Shackleford 1955) in Redford, and Ft. Leaton in Presidio (Ing 1971) are the only archeological sites in the immediate vicinity which have been at least partially excavated.

THE SITES

A total of 30 archeological sites was recorded during the 11-day field period, including the two sites previously recorded by Tunnell and Mallouf during a Wild River Project reconnaissance which are incorporated into this report. Only one site, 41PS128, represents historic occupation, although reutilization of prehistoric shelters by sheepherders was noted frequently. Several areas containing very thin lithic scatters and isolated surface finds were observed but not given site designations.

Surface collection by relic hunters has occurred at the majority of the sites, but only a few subsurface disturbances were noticed. Local residents confirmed that exploitation of area sites has long been a popular hobby and source of economic livelihood. To help avoid such exploitation, specific site locations and descriptions have been deleted from this report; however, mapped plottings of exact locations and survey forms are available to responsible persons for scientific purposes.

For convenience and comparative purposes, the sites and their informational data have been presented in chart form (Table 1). The sites have been categorized and discussed according to the following divisions: river sites, major tributary canyon sites, and arbitrary sample locality sites. Individual sites located within these areas have been subdivided into the following site types: gravel terrace site; sand/silt terrace site; sand/silt/gravel terrace site; rock shelter site; unusual location site. By viewing the sites within these natural ecological divisions it is hoped that subsistence and settlement patterns will be more accurately distinguished.

River Sites

Eight archeological sites were located in the riverine topographical division: Site 41PS116, Site 41PS117, Site 41PS118, Site 41PS119, Site 41PS120, Site 41PS122, Site 41PS124, and Site 41PS125. All are located on sand/silt or sand/silt/gravel terraces above the Rio Grande (Fig. 2a, b). Along this portion of the river the terraces and floodplain are not wide enough to support large agricultural fields as are those areas to the north of Colorado Canyon in the Redford Bolson. Colorado Canyon has steep vertical walls of resistant Santana Tuff and only an occasional high terrace suitable for occupation. Immediately east and west of the canyon are favorably situated terraces, however, several of these terraces and their associated sites have been partially or totally destroyed by the construction of Highway 170.

No major variation in the course of the Rio Grande at this particular locale has occurred since late prehistoric times to alter our view of the prehistoric setting. The river's biotic community is also basically unchanged except for recently introduced intrusives such as salt cedar. Baccharis, tree tobacco, mesquite, catclaw, acacia, and carrizo (Georgia cane) are the principal vegetants (Mary Butterwick 1975: personal communication).

Many factors contribute to the selection of sandy river terraces as occupation or specialized function areas. Of primary importance is the fact that these terraces provide flat surfaces with soft sand in contrast to the typically rugged, rocky terrain of the general area. Exploitation of fish, availability of a constant water source, and difficulties in overland travel (Kroeber 1953:143-146) may have resulted in a concentration of the population along the river. Population size and stability are limited by the specific environment and effectiveness of the particular subsistence technique (Trigger 1968:61). It is assumed that these sites were inhabited by small socio-cultural groups on a seasonal or intermittent basis because of their dependence on a seasonally variable economy of gathering, hunting, fishing, and, possibly, very limited agricultural attempts.

Although seasonality of occupation can only be postulated at this phase in the research, it appears that habitation during the winter would be advantageous if plants were less productive and more emphasis were placed on fishing to accompany the hunting subsistence. Also, although terraces provide no protection from winter winds, the danger of flash flooding is not as likely as it is during the torrential rains of the summer months.

Site 41PS125, which has the greatest horizontal extent of the river terrace sites, has an abundance of burned rock and lithic debitage scattered on a mesquite-covered dune ridge overlooking the lower elevated floodplain. The midden deposit and lithic debitage becomes more shallow vertically and more sparse horizontally as the site extends to the northwest into the flatter, duneless portion of the terrace which is sparsely covered with small bushlike mesquite, creosote bush, acacia catclaw, and various cacti. Around the perimeter of this alluvial terrace are large igneous boulders from the slopes of Colorado Mesa and several smaller colluvial pediments. Fifteen bedrock mortars were located in these boulders and two slab metates were observed. We later witnessed the collection of one of the metates by Mexican nationals. These grinding implements may indicate either continual occupation or long-term seasonal reoccupation of the site for plant gathering and processing activities. Gravel bars in the river and colluvial

TABLE 1

Site Number	Elevation (feet)	**Type of Site	Area of Occupation (sq. m.)	Horizontal Distance from Water (ca. m.)	Vertical Distance from Water (ca. m.)	CULTURAL DEBRIS							Identified Lithic Material Types Collected	Present Condition
						Perishables	Ground or Pecked Stone	Chipped Stone Artifacts	Firecracked Rock or Hearths	Flaking Debitage	Faunal Material	Rock Art		
41PS113	2800	Sh	300M	1,900M *200M	66M	None	None	None	Yes	Yes	None	None	chert—w, g, br*** quartz chalcedony	partially eroded; vandalized
41PS114	3600	Sh	2,054M	3,900M *200M	133M	None	Yes	None	None	Yes	None	Yes	chert—r	vandalized
41PS115	2500	Sh	3,500M	400M *30M	15M	None	Yes	None	Yes	Yes	None	None	chert—r, g, b, t, y quartz agate—p rhyolite palsanite	partially eroded
41PS116	2450	ST	2,500M	50M *50M	10M	None	None	None	Yes	Yes	None	None	chert—g, w, r, t, y agate—p rhyolite paisanite	partially destroyed (construction)
41PS117	2480	GT/ST	900M	25M *15M	2M	None	None	None	Yes	Yes	None	None	chert—b, r, g quartz sandstone rhyolite paisanite	intact
41PS118	2480	GT/ST	7,500M	75M *75M	6M	None	None	None	Yes	Yes	None	None	chert—r, g, w, b, y sandstone rhyolite paisanite	partially eroded
41PS119	2360	ST	625M	50M *50M	4M	None	None	None	Yes	Yes	None	None	chert—w, t, g, y, n quartz slate sandstone	partially eroded
41PS120	2360	ST	5,000M	50M *50M	5M	None	None	None	Yes	Yes	None	None	chert—r, g, t, br slate quartz rhyolite paisanite	partially eroded and construction damage
41PS121	2480	GT	800M	1,000M *75M	10M	None	None	None	None	Yes	None	None	chert—t, r, g rhyolite—p, r, br paisanite	intact
41PS122	2480	ST	1,000M	75M *25M	3M	None	None	None	Yes	Yes	None	None	chert—r, t, t, b slate quartz rhyolite	partially destroyed (construction)
41PS123	2500	Sh(UL)	3M	125M *125M	40M	Yes	None	None	None	None	None	None	None	destroyed
41PS124	2520	GT/ST	3,750M	250M *250M	10M	None	Yes	Yes	Yes	Yes	None	None	chert—b, r, g, t rhyolite—p, r paisanite sandstone chalcedony agate	partially destroyed (construction)
41PS125	2380	ST	75,000M	150M *150M	5M	None	None	None	Yes	Yes	None	None	chert—r, g, t, y, b paisanite rhyolite—r, p sandstone	vandalized
41PS126	3240	GT/ST	1,250M	20M *15M	5M	None	None	None	Yes	Yes	None	None	chert—r, y, g, t rhyolite quartz sandstone	partially eroded
41PS127	3560	GT	3,500M	1,700M *40M	10M	None	None	None	Yes	Yes	None	None	chert—r, g novaculite sandstone	partially eroded

41PS128 (historic)	3800	GT	2,500M	60M *60M	20M	None	Yes	None	None	None	None	None	None	intact
41PS129	3760	Sh	200M	20M *15M	1M	None	None	None	None	None	None	None	None	eroded
41PS130	4200	Sh	120M	450M *450M	200M	Yes	None	None	Yes	Yes	Yes	None	chert–g novaculite	vandalized
41PS131	2600	Sh	70M	1,400M *150M	20M	None	None	None	Yes	None	Yes	None	None	intact
41PS132	3140	Sh	450M	50M *40M	26M	None	Yes	None	None	Yes	None	None	chert–g, r, y, t, b chalcedony quartz novaculite	partially eroded
41PS133	3120	ST	150M	25M *15M	5M	None	None	None	Yes	Yes	None	None	chert–r, t, g, y quartz rhyolite	intact
41PS134	2740	GT	2,500M	40M *20M	10M	None	Yes	Yes	Yes	Yes	None	None	chert–r, g, t, y chalcedony novaculite	partially eroded
41PS135	3700	GT	2,400M	400M *50M	5M	None	None	Yes	None	Yes	None	None	chert–g, r, y limestone chalcedony agate novaculite red lava flow silicified volcanics	partially eroded
41PS136	3500	GT	5,000M	1,000M *50M	5M	None	None	Yes	None	Yes	None	None	chert–g, t, r novaculite volcanic silicates welded lava flow–y rhyolite	partially eroded
41PS137	3580	GT	33,750M	25M *25M	5M	None	Yes	Yes	Yes	Yes	None	None	chert–r, g, y novaculite chalcedony agate	partially eroded
41PS138	3140	GT	10,000M	50M *25M	5M	None	None	None	Yes	Yes	None	None	agate w/y/b combination agate–p, r chert–w, t quartz rhyolite–p, r basalt	partially eroded
41PS139	3840	GT/ST	12,250M	30M *15M	7M	None	Yes	Yes	Yes	Yes	None	None	chert–r, y, b agate–p novaculite limestone silicified volcanics	partially eroded
41PS140	2650	Sh	1,000M	450M *100M	25M	None	Yes	Yes	Yes	Yes	Yes	None	chert–g, r, t, w quartz rhyolite–r, p paisanite	partially eroded
41PS172	2350	GT/ST	5,000M			None	None	Yes	Yes	Yes	None	None	chert–t, br, g, n chalcedony rhyolite	partially eroded
41PS173	2350	GT/ST	2,000M			None	None	None	Yes	Yes	None	None	chert–r, g, w, br rhyolite	partially eroded

*Estimated distance (M) to prehistoric water source

**Type of sites:
Sh – rock shelter site
GT – gravel terrace
ST – sand/silt terrace
Sh(UL) – unusual location shelter

***Color symbols:
r – red
g – gray
b – black
t – tan
y – yellow
p – purple
br – brown

FIGURE 2

a. Sand/silt terrace of Site 41PS119; Rio Grande and Mexico in background.

b. Site 41PS118 above the Rio Grande; Bofecillos Mountains to the north.

and alluvial gravels from nearby pediments and arroyos offer convenient areas for lithic resource collection. Site 41PS121 is a lithic procurement area possibly associated with this site. No structural features were observed during surface inspection of Site 41PS125, but this does not exclude the possibility of their existence.

The smaller river terrace sites are similar in appearance to the description above except that they display less cultural debris. Burned rocks and thinly scattered lithic debitage are the extent of the cultural material except for two surface features observed at Site 41PS124. Two of the river sites, Site 41PS122 and Site 41PS124, have been bisected by the construction of Highway 170, and Site 41PS116 has been partially destroyed by the construction of a transient workers' camp, garden, and corral. Easy access to the sites offered by Highway 170 has contributed to intensive collection by relic-hunters.

Site 41PS124 is located on a high colluvial/alluvial terrace at the base of a steep igneous mountain rising above the second terrace of the Rio Grande. In addition to bedrock mortars, lithic debitage, burned rock and one Perdiz-like projectile point, the remains of two circular "wickiup" rings of igneous lava flow rocks were observed. The wickiup rings were two m and four m in diameter and contained midden deposit at least 30 cm in depth as evidenced by a recent pothole. No other sites were located during this survey which displayed similar surface features, but a large site of "wickiup" rings southeast of Redford is known to local informants.

Located on a low sand/gravel terrace at the confluence of the Rio Grande and Rancherias Creek, Site 41PS117 varies from the other river sites in that it appears to be a possible tuberous plant baking area (ring midden) as evidenced by a circular area of burned rock. This terrace location probably was selected for several reasons: proximity to Colorado Mesa which supports abundant stands of lechuguilla and sotol; proximity to Site 41PS122, a possible habitation site; and abundance of river cobbles and colluvial gravels in association with soft, loose sand for easy digging of the baking pit.

Major Tributary Canyon Sites

The four major tributary canyons of the Rio Grande which were systematically surveyed include: Madera Canyon, Panther Canyon, Rancherias Canyon, and Topado (Oso) Canyon. These major canyons are deeply incised into the fault-block zone of the Bofecillos Mountains area. This zone displays the greatest relief of the area with steep slopes and vertical cliffs forming the walls of the canyons (McKnight 1970:30). These north-south oriented canyons are barriers to east-west overland travel but provide natural pathways for access from the Rio Grande into the rugged uplands of the Bofecillos Mountains. At present, all of the canyons have intermittent and perennial water supplies in the form of either seeps, springs, tinajas, flowing creeks, or a combination thereof. In all probability, during the last 2000 years surface water abundance in the canyons was about the same as it is at present.

A variety of plants are located in the biotic community of the canyons because it incorporates vegetation of stream bed, colluvial slope, stream terrace, and mesa areas (Mary Butterwick 1975: personal communication).

The abundance of natural resources makes these areas ideal for occupation and exploitation. Although each canyon is physiographically unique, the only topographically feasible areas for occupation in all canyons are on alluvial stream terraces and in rock shelters. The canyon slopes are usually too steep to be conducive to habitation, and rims and ridges are often at the tops of steep cliffs overlooking the narrow canyons, making access to the water source in the streambed difficult. Collectively, the canyon sites include seven terrace sites, one historic and six prehistoric, and eight prehistoric rock shelter sites.

The historic site, Site 41PS128, consisting of two adobe brick structures with sotol and ocotillo stalk ceilings (Fig. 3a), is located at the head of Panther Canyon on a gravel terrace above a constant spring. Some of the artifacts observed in and around the structures included: canning jars, handmade furniture, pots, pans and kitchen utensils, tools, a woodburning stove (Fig. 3b), glass and pottery sherds, a picture of the crucifixion, and three recycled prehistoric metates. Local informants report that these buildings were constructed "around the turn-of-the-century" and have been intermittently occupied throughout the years.

Terrace site 41PS139 is the only prehistoric or possible historic Indian site in the canyon at which surface features were observed. The site consists of a large area of profuse lithic debitage, burned rock and ash, and many bedrock mortars in the dry streambed. Also associated is a dense concentration of "ovenlike" hearths (Fig. 4b) hidden in a thick stand of mesquite and catclaw on the alluvial sand/silt terraces on either side of Rancherias Springs (Fig. 4a). No data on similar "ovenlike" hearths could be found for comparative purposes. Because no diagnostic artifacts were observed in direct association with any of the estimated 50 to 75 hearths, data weighs equally for either prehistoric or historic Indian occupation. Several functional implications for this type of hearth can be hypothesized: (1) use as ovens for the baking

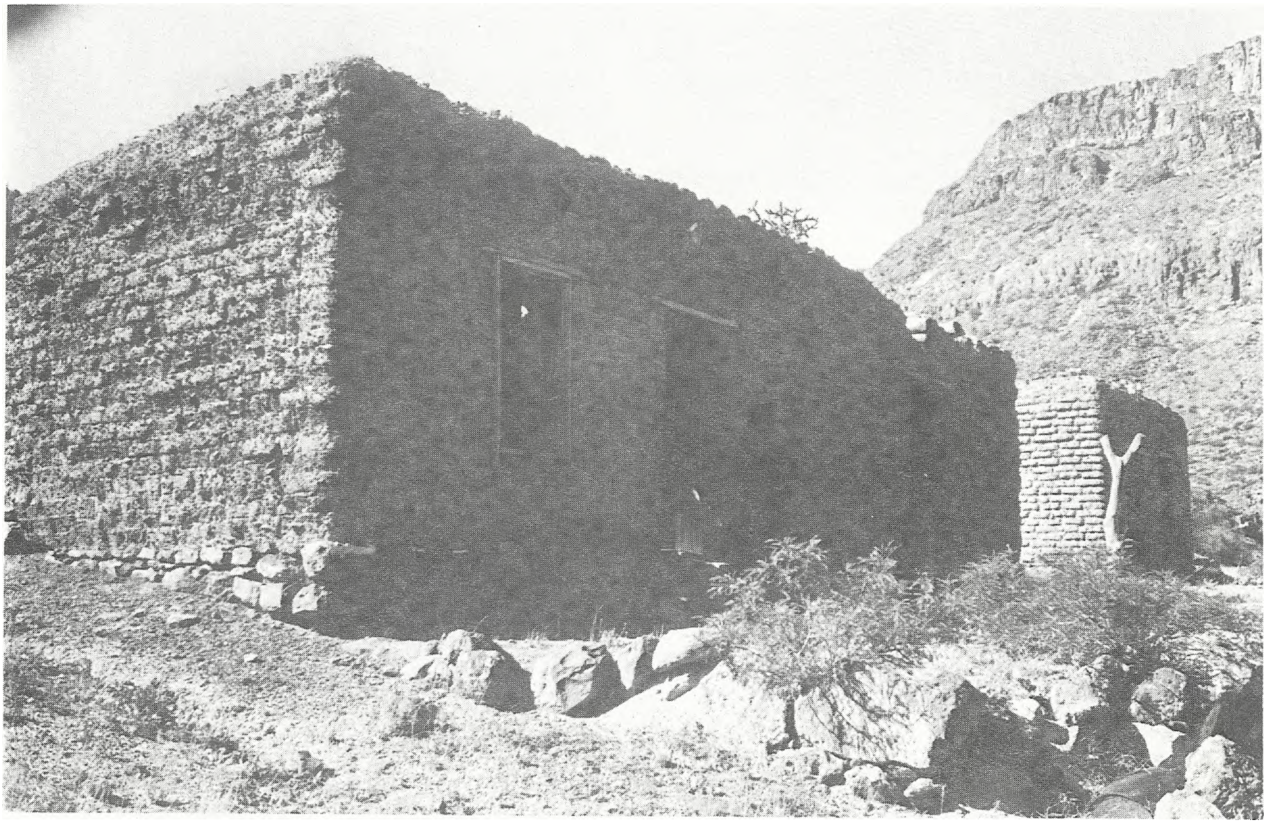
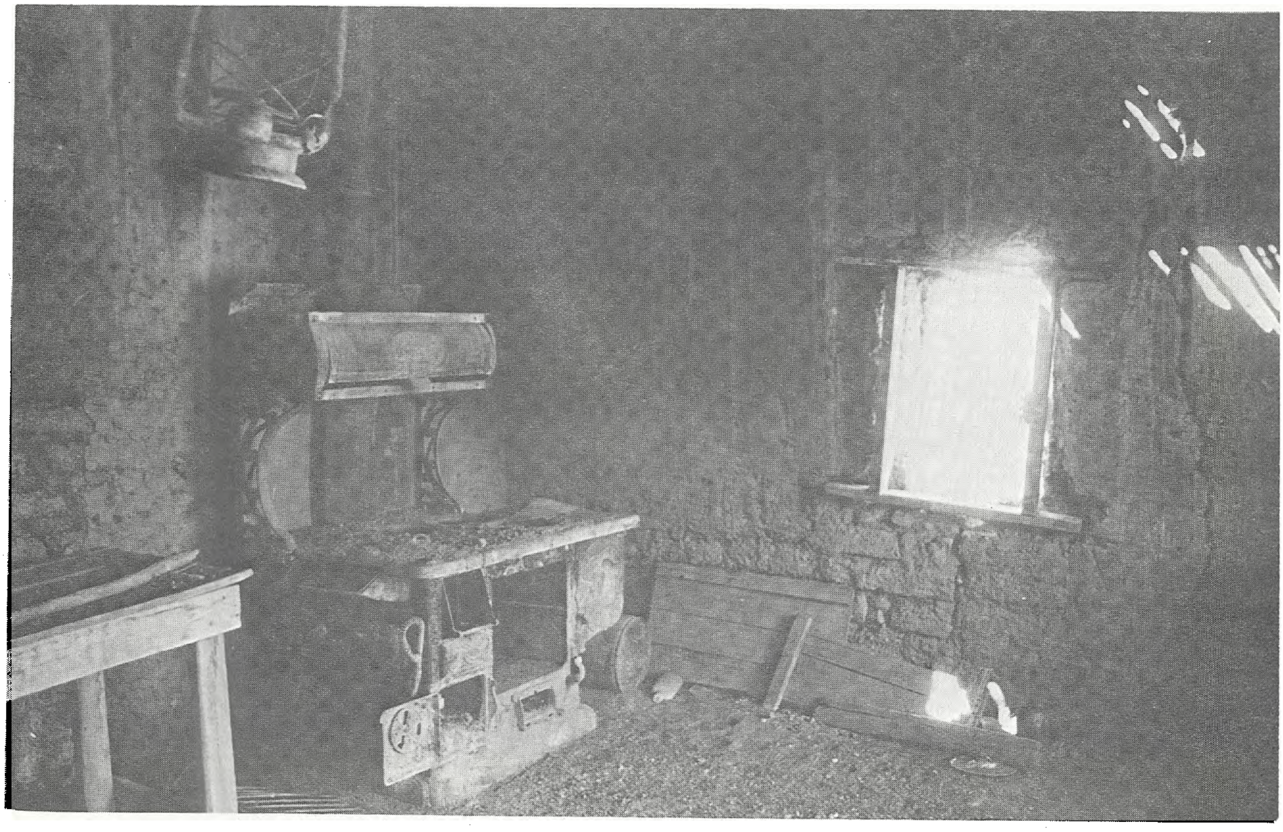


FIGURE 3

a. Historic adobe structures of Site 41PS128 in Panther Canyon.



b. Interior of adobe with castiron woodburning stove, jars, utensils, and crude handmade furniture.

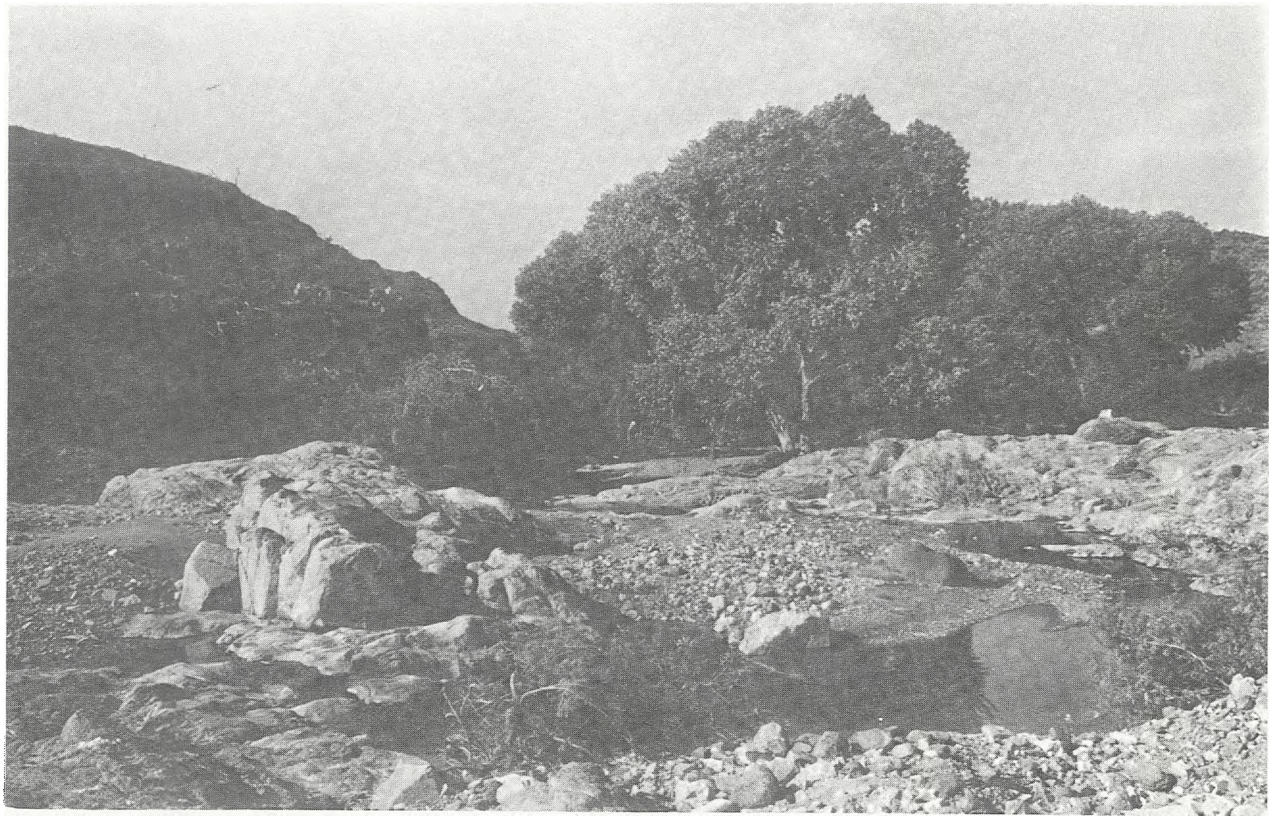
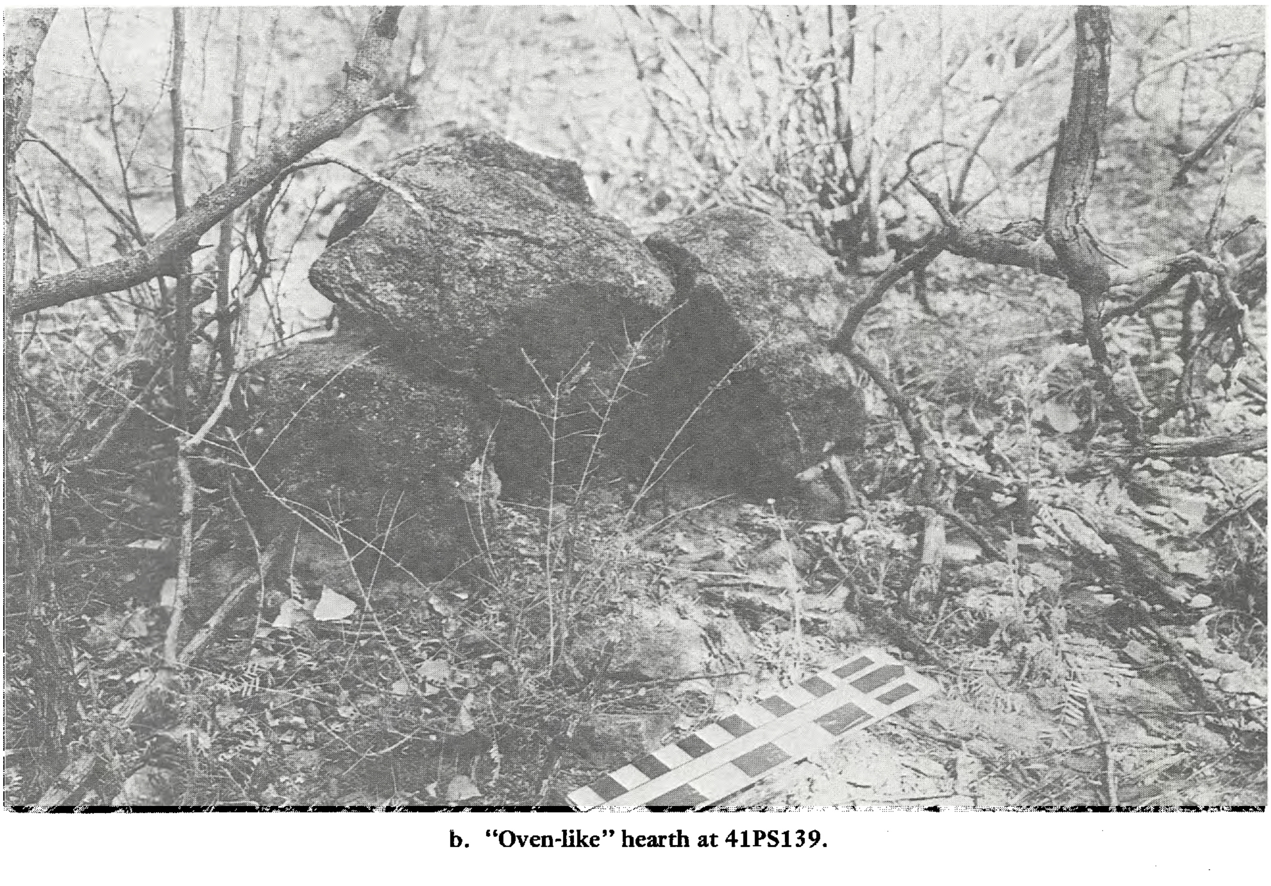


FIGURE 4

a. General view of Rancherias Springs and Site 41PS139.



b. "Oven-like" hearth at 41PS139.

of sotol or other tuberous plants; (2) use as individual "fireplace" hearths with only one open side for concentrating the direction of heat, or (3) use of the top-covering rock as a "radiator" to disperse heat over a larger area or for cooking purposes, such as cooking tortillalike breads.

The remaining terrace sites have no outstanding characteristics, being distinguished as occupation areas only by the scatter of lithic debitage, burned rock, midden deposit, or occasional grinding implements. The main variation between the sites is in the horizontal extent of the occupied area and the numerical frequency of the cultural remains within each occupation locale.

The eight rock shelter sites within the canyon division, with the exception of Site 41PS130, Site 41PS131, and Site 41PS129, are situated along the slopes of terraces above the streambeds at elevations high enough to protect them from possible floodwaters but within easy access of the immediate water supply. Sites 41PS130 and 41PS131 are located in the high, exposed tuff faces of igneous mountains while Site 41PS129 is situated within the streambed and has been washed free of any midden deposit, leaving only a single blackened ceiling as an indicator of human utilization. The rock shelters can be geologically divided into two categories: rock shelters in soft volcanic tuff and shelters formed by igneous boulders (Figs. 5a, b; 7; 8a, b).

The majority of the rock shelter sites have associated talus slopes exhibiting cultural debris similar to that found on terrace sites (Fig. 7). Smoke-blackened ceilings and evidence of more recent historic reutilization are not uncommon (Fig. 8a). Bedrock mortars and metates were found in direct association with several of the shelters.

Evidence of human occupation at Site 41PS140 (Fig. 8a) is exhibited by bedrock mortars, smoke-blackened ceilings, burned rocks, lithic debitage, dark midden deposition, mussel shell, protective dry-rock walls and recent graffiti. Most of the other rock shelter sites did not display such a diversity of cultural material, but occupation was represented by at least one of the above-mentioned cultural indicators. No pictograph-bearing shelters were recorded within the major tributary canyons and no utilized rock shelters were located within the surveyed areas of Madera Canyon.

Arbitrary Sample Locality Sites

Sites classified under this division represent habitation or specialized function locations observed during "spot checking" of arbitrarily selected locales within the survey area. Seven sites are categorized in this grouping: four rock shelter sites, three of which are within the same unnamed arroyo and one unusual occurrence in an igneous rockslide; one lithic procurement area on a gravel terrace; and two open, gravel terrace sites along Fresno Creek which were located during a Wild River reconnaissance and, although out of the specific Colorado Canyon survey area, seem to be culturally associated with the other sites.

The most intriguing of these sites, Site 41PS114, includes two utilized rock shelters, one for habitation and one as a specialized function area. The site is located at the head of an unnamed arroyo on the vertical tuff cliff of Cerro de las Burras (Fig. 9a). The pictograph-bearing rock shelter is not feasibly located or formed for habitational purposes due to difficulty in access and the steep angle of the spalling tuff floor. However, it is magnificently situated, offering a panoramic view of the surrounding terrain (Fig. 9b) which might suggest that location possibly was a major factor in the selection of this rock shelter for the housing of the culturally significant pictographs (Fig. 10a-f). The pictograph style is thought to be regionally isolated in the Bofecillos Mountains except for similar pictographs at the Indianhead Mountain Site in Brewster County, Texas, which might be attributed to the same peoples on the basis of the size of the symbols and the exclusive use of black pigment (Miriam A. Lowrance 1975: personal communication). The pictographs did not reveal any evidence which might indicate temporal placement.

The habitation shelter of Site 41PS114 is assumed to be associated with the pictograph shelter, but no conclusive evidence was found to confirm this assumption. It is located at a lower elevation and on the opposite slope of the arroyo from the pictograph shelter. The rock shelter manifests a thick midden disturbed by "potholes" and two associated bedrock mortars and scattered lithic debitage.

Site 41PS115 is composed of several utilized rock shelters with smoke-blackened ceilings concentrated in a large volcanic tuff formation which has been eroded by wind and water solution to form excellent small habitation shelters (Fig. 8b). Many bedrock mortars were found in the nonresistant tuff. Reutilization by sheepherders is evidenced by the construction of protective dry-rock walls enclosing several of the rock shelters and a dry-rock corral at the base of the formation. A talus of dark midden deposit, lithic debitage, and burned rock was observed in front of the largest rock shelter which faces into the present corral area.

Located in an igneous boulder rockslide immediately north of Highway 170, Site 41PS123 (Fig. 11) was relocated for us by Simon Moreno, who first discovered this storage shelter in 1931 while herding sheep. From the rock shelter he recovered a four-foot

FIGURE 5

a. Igneous boulder forming rock shelter at Site 41PS132.

b. Two igneous boulder rock shelters at Site 41PS127.

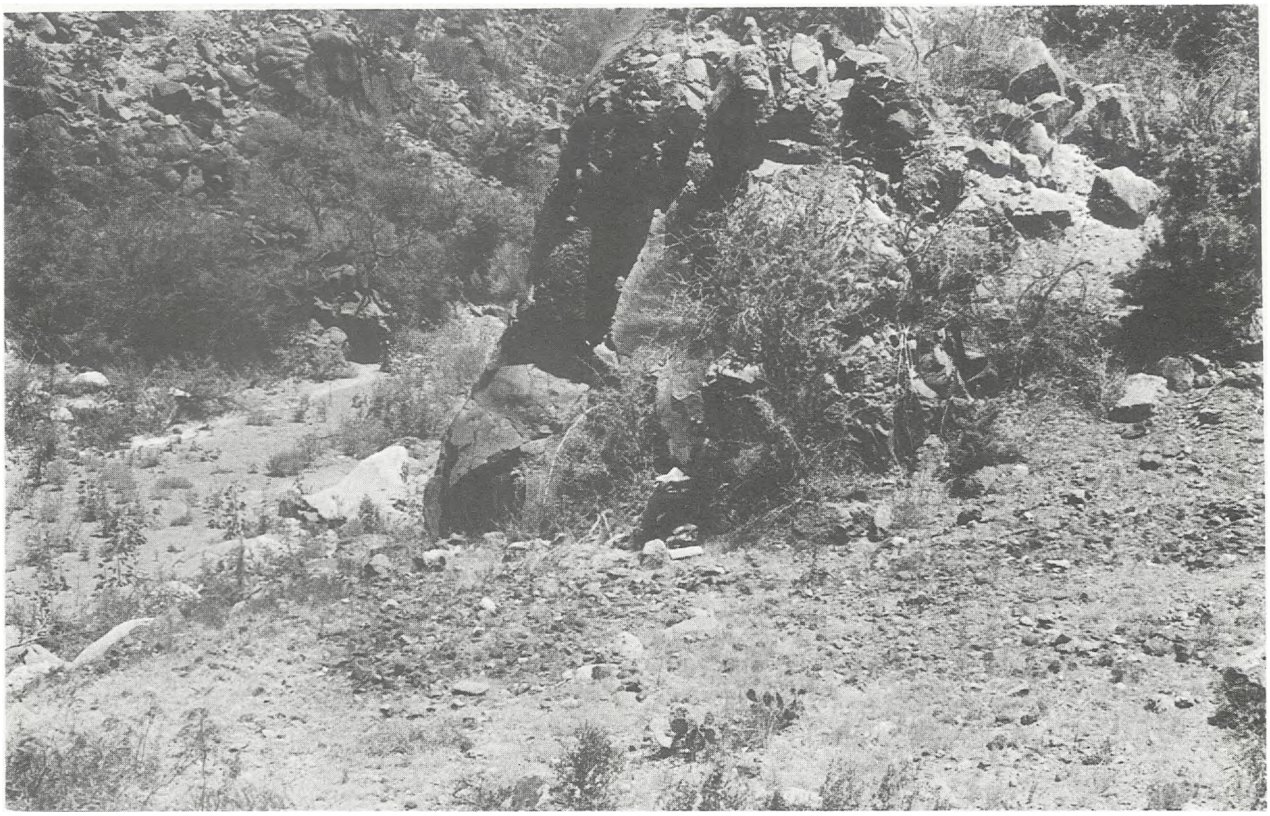


FIGURE 6

Silt/gravel terrace of Site 41PS126 along Panther Creek; burned rock and midden eroding into the streambed.

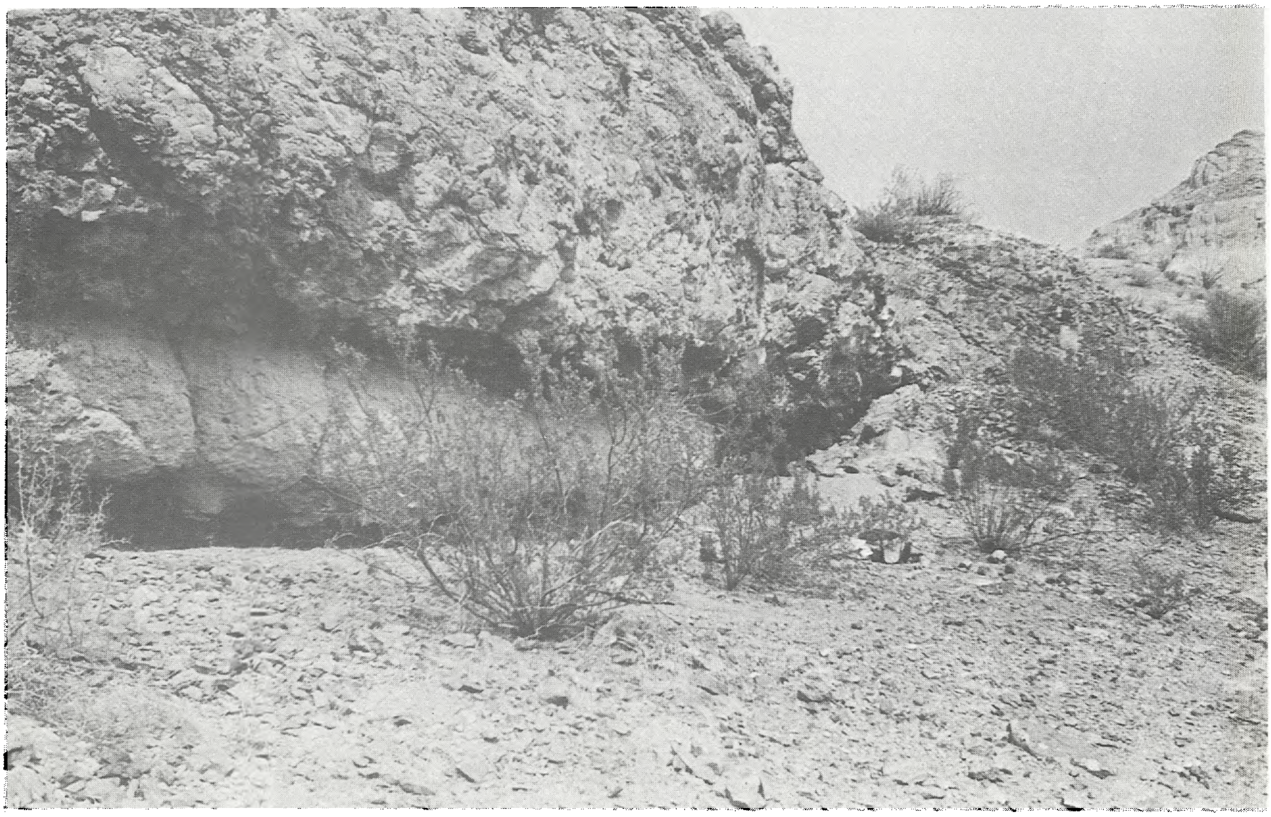


FIGURE 7

Igneous and volcanic tuff overhang at Site 41PS113; talus continuing down slope.

FIGURE 8

a. Rock shelter formed in nonresistant tuff at 41PS140; dry rock wall is evidence of historic reutilization by sheepherders.

b. Rock shelters in large tuff formation of Site 41PS11 5.

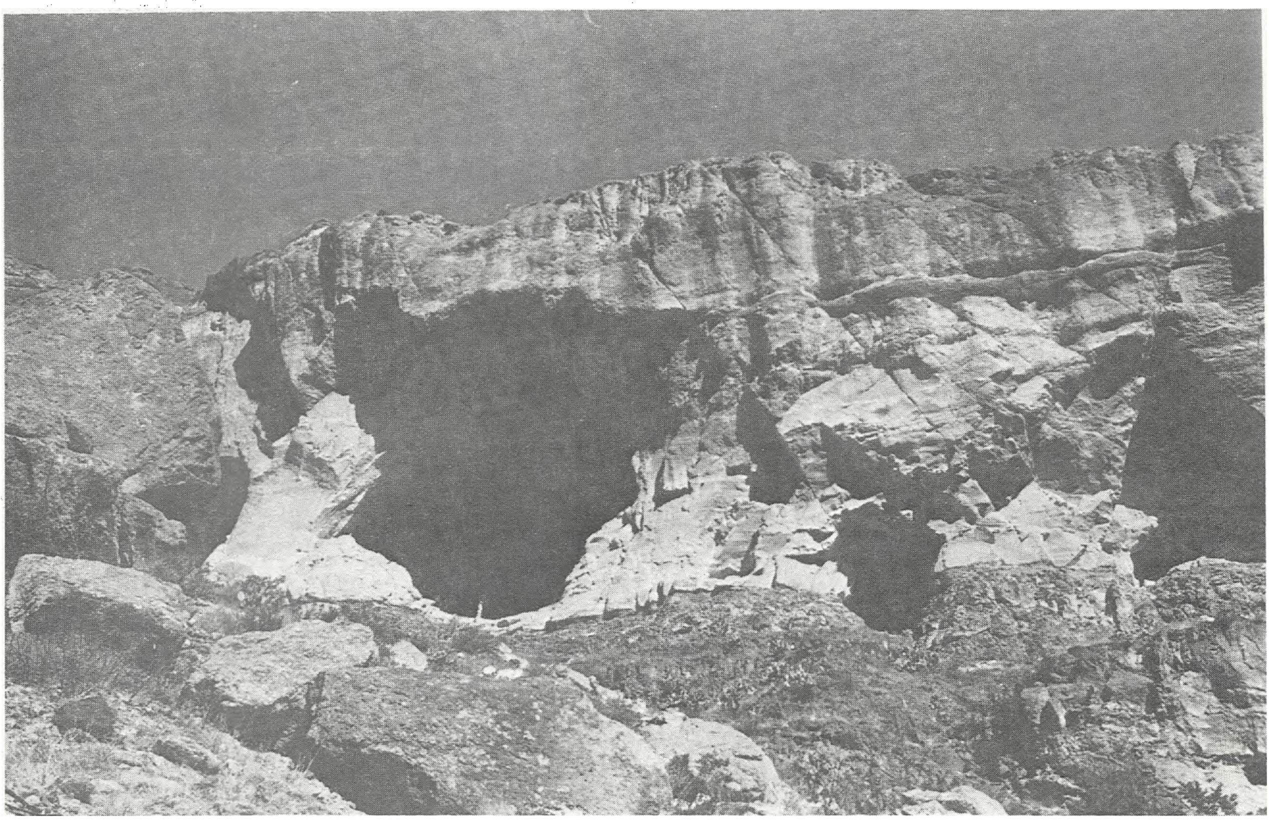
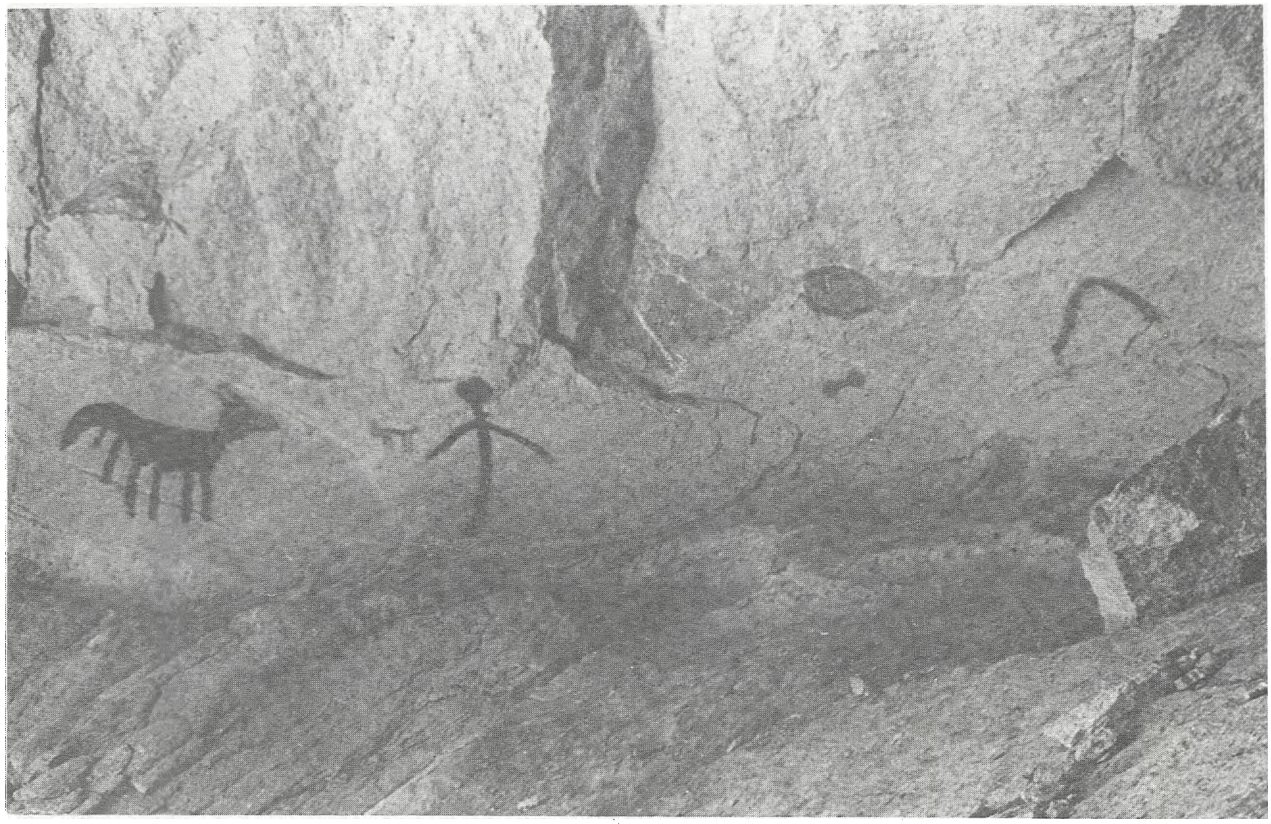


FIGURE 9

a. Pictograph-bearing rock shelter at Site 41PS114 on left; note human figure at entrance for scale.

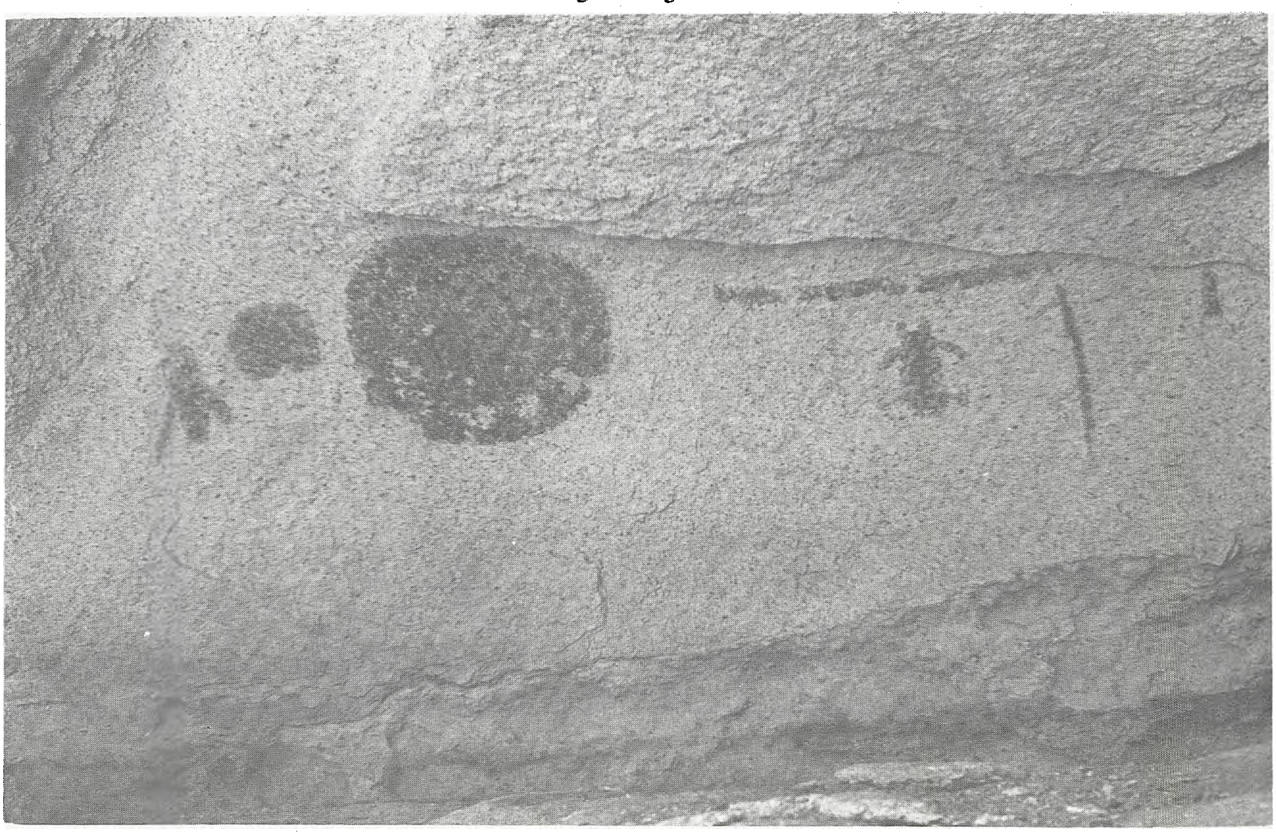
b. View from inside Pictograph-bearing rock shelter looking southeast.



a.

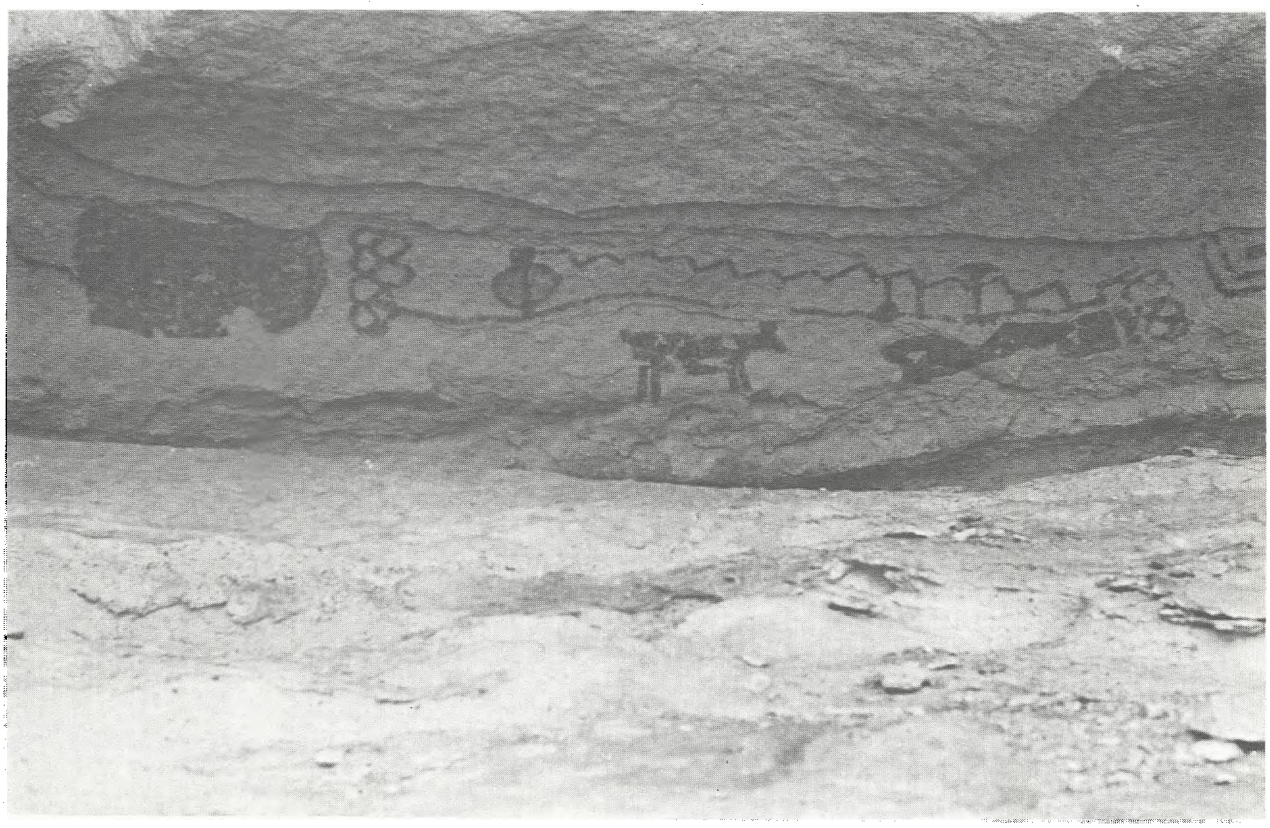
FIGURE 10

a-f. Pictographs of Site 41PS114;
Panels a-f follow from left to right along the back wall of the rock shelter.



b.

c.



d.

e.

f.

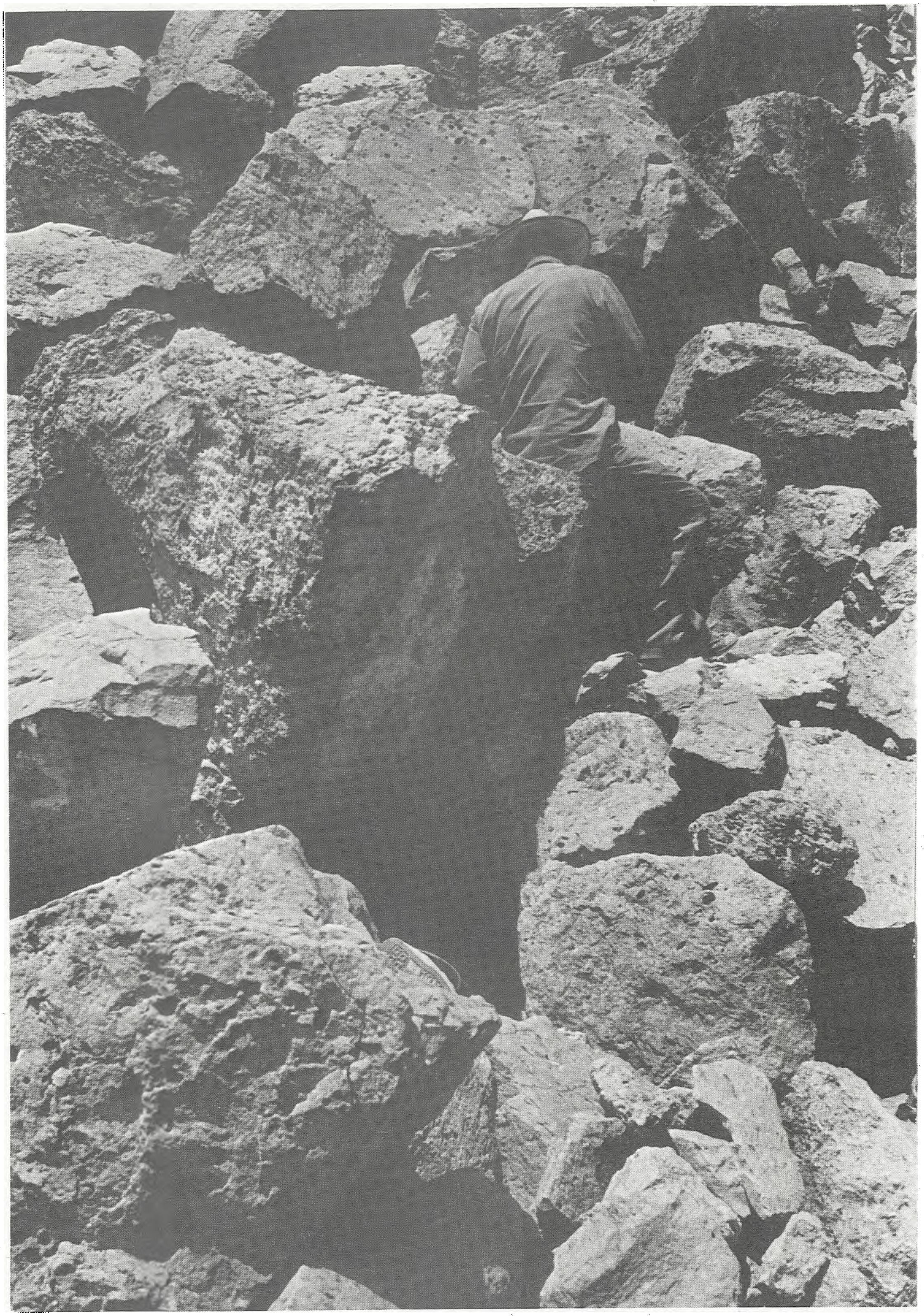


FIGURE 11

Rock shelter Site 41PS123 in igneous rock slide; note the tennis shoe of the person inside the shelter.

bow, a corn cob "doll," several utilized flakes, and woven plant fiber mat and bedding material. When reinvestigated, remnants of the fibrous bedding and a broken ocotillo stalk were observed.

Site 41PS121 is the only recorded lithic procurement area, although other smaller areas along this same unnamed drainage system showing limited aboriginal testing and knapping of cobbles were noted. Flakes and numerous cores were observed and a small sample was collected for lithic material type identification. It appears as though these people were collecting and testing Rio Grande river cobbles located on this gravel terrace for quality of knapping characteristics. Very few secondary or tertiary flakes were found, indicating that cobbles of acceptable quality were possibly removed from this site for further knapping at another location. Site 41PS125, which is a large habitation site, is in proximity and possibly is associated directly with this lithic procurement area. The samples collected for identification show rhyolite cobbles to be the main type of lithic material utilized from this particular source (Leon Byrd and Cader Shelby 1975: personal communication).

The gravel terrace sites located along Fresno Creek are typical of those open terrace sites of the major tributary canyon area. They display no surface features but have scattered lithic debitage and burned rock to indicate occupation.

DISCUSSION

Although the main focus of this reconnaisance and report is inventory and evaluation, it is felt that some statements need to be made as a synthesis of the previously presented data. A complex interrelationship exists between site type, site size, sociocultural implications of sites, individual site locations and their position within the settlement system, and subsistence patterning. These components cannot be discussed or comprehended as individual entities but must be viewed as dependent variables within a multicomponent system which reflects a response to both social and physical environments. For definitional and organizational purposes, terms presented by Plog and Hill (1971:8) will be used to categorize these components: (1) formal variability in sites; (2) variability in the temporal loci of sites, and (3) variability in the spacial loci of sites. Because this reconnaissance did not include surface collection and subsurface testing, only limited data is available for consideration. Formal and temporal variability of all sites is discussed collectively, but spacial variability is considered separately within the two major topographic divisions and then compared and discussed. An attempt at coordinating all arbitrary locality sites would be an invalid association of topographically variable site locations which would be likely to yield questionable results.

Two aspects of formal variability are considered: site types and site size. Sites located during the reconnaissance have been classified topographically for discussion but may also be categorized as open sites and rock shelter sites. All open sites are located on unprotected terraces, while rock shelter sites are within protected areas. At this stage of investigation, no functional classification of sites would be valid. However, a general framework for a functional division can be postulated for future testing. A tentative division of three functional site types is hypothesized from the observed surface debris: (1) hunting and/or lithic resource procurement, evidenced by lithic debitage, (2) plant gathering and processing and hunting camps, designated by both grinding implements and lithic debitage, and (3) habitation areas, suggested by the permanence of bedrock grinding implements, midden deposits, and density of cultural debris. It is believed that, through future intensive work, a sound functional classification can be provided.

Site size, as exemplified in Table 1, shows considerable variability. Open terrace sites range in size from 150 to 75,000 square meters, while rock shelter sites range from 3 to 3,500 square meters. Site size, along with additional variables, is often used to indicate population size. No attempt is made to estimate a numerical size of populations utilizing these site locations. However, based on the hypothesized hunting and gathering economy, it is suggested that occupation and utilization were probably by small sociocultural groups organized by kinship or clans.

Temporal variability concerns the placement of sites within a time frame which includes cultural affiliation and chronological positioning. Because of the virtual absence of diagnostic artifacts, it would be premature to attempt to associate any of the sites with a specific culture or place them into an established chronology. In general, the lithic debitage and grinding implements suggest a non-specific hunting and gathering economy which is indicative of the Archaic stage of development. Not all groups made the transition from the Archaic to the Neo-American developmental stage, and it should be emphasized that an Archaic subsistence system could be manifested during the Neo-American chronological time period. The possibility of the sites as temporary hunting and gathering stations associated with later permanent agricultural sites, such as the Polvo site (Shackelford 1955), should not be disregarded but rather should be considered as an hypothesis for testing during future work.

Spacial variability is of the utmost importance because site localities are not chosen at random. They are preferred areas which reflect a sociocultural response to the distribution of natural resources, the environmental and cultural stresses within the ecosystem, and the position of other site localities which form the settlement pattern. If the settlement system is dependent on the resources and their distribution, the principal exploitable resources must be recognized. For this survey area they are: (1) habitable areas, (2) water, (3) plants, (4) animals, and (5) lithic resources. Environmental stress is produced by the topography and climatic conditions. Evidence of social stresses, such as epidemics and warfare, has not as yet been recorded in this area.

A scarcity of flat, rock-free terraces high enough to provide flood protection gives the actual selected site location value as a resource in itself. The location becomes more valuable if it also provides other on-site resources or is centrally located to other resources (Plog and Hill 1971:11), thus minimizing the effort expended in exploitation. The majority of the river terrace sites offer several on-site floral resources. At this time, however, it is impossible to know if these same plants existed on these locations during prehistoric times. Areas adequate for limited agricultural fields are found on several of the terraces. The river sites are not as centrally located to some desirable ecological niches as are the major tributary canyon sites; however, access into tributary canyons from the Rio Grande is not difficult.

In this semiarid country water is probably the primary resource. Because this portion of the Rio Grande is below the confluence with the Rio Conchos, a constant water supply is assured on a year-round basis. The only hazard encountered is the possibility of flooding, a factor which probably influenced the choice of high rather than low terraces. The riverine biotic community is somewhat limited in numbers of economic plants but proximity to mesas and colluvial ridges increases the diversity of the available exploitable flora. River sites are not well-positioned for exploitation of large fauna. Most larger animals, such as the mule deer, inhabited the uplands rather than the valley area; however, smaller animals (rabbits, coyotes, rodents, etc.) would be readily available in the immediate site area.

Lithic resources are available in the form of alluvial cobbles from the gravel bars of the Rio Grande and adjacent arroyos. Some exploitable colluvial gravels also can be collected from nearby ridges. The identified sample from Site 41PS121, a lithic procurement area, shows an abundance of various types of rhyolitic cobbles being utilized.

The geology of the area affects the choice of site locations. As mentioned, the sandy terraces are the exclusive riverine areas observed to have been chosen for occupation. Difficulties in travel caused by the surrounding terrain possibly affected the choice of the river area for occupation. The Rio Grande was available as a waterway for east-west travel, while the canyons provided north-south pathways to the uplands. Climatic conditions are generally not severe in this region, except for the intense heat of the summer sun. Although terraces provide no protection from either sun or winter winds, except for the shade of a few mesquite trees, temporary shelters easily could have been constructed because of the soft ground of the sandy terraces as opposed to the rocky surfaces of most areas.

The canyon sites are more numerous than the river sites, a fact that probably is affected by the greater availability and diversity of resources within the canyons. As with the river sites, the flat stream terraces of the canyon area and the protected shelter areas are valuable resources because of the limited number of feasibly habitable locales within the steep canyons. Most of the canyon sites provide some floral and lithic sources as possible prehistoric on-site resources. These sites are positioned more advantageously than the river sites for a nonspecialized hunting and gathering economy because they are located in a central position between the Bofecillos uplands and the lowland river areas, providing easy access to either area. Water is available in each of the canyons; seeps and trickling springs were observed in all surveyed canyons, while Rancherias and Tapado Canyons had more abundant water collected in tinajas and flowing in larger creeks.

The biotic communities of the canyon areas are far more inclusive than those of the river area. Several specific biotic communities are represented, thus allowing prehistoric exploiters of plants to obtain more abundant and diverse yields with less expenditure of energy. Hunting of local fauna probably was very rewarding because the canyons offer animals the same necessary resources as they offer their human inhabitants: water, food, and habitation areas. Being territorial, animals will remain within their range as long as these necessities are provided. Some areas near springs which appeared favorable for human utilization showed no cultural evidence; however, in dry country, some watering holes must be reserved for animals so as not to drive them from the area (Butzer 1971:407). This spacing and sharing of resources may have a direct effect on the distribution of the sites.

Although no lithic procurement or quarry areas were located in the canyons (Table 1) during the survey, the lithic resources, as identified from the collected samples, are all available from local sources in the Bofecillos Mountains. All canyon sites are within a half day's walk of the Rio Grande for collection of lithic materials from river gravel deposits, as exemplified by Site 41PS121.

Geologically, the canyons provide more advantageous features than disadvantageous ones. Terraces and shelters are found which provide living and working space, while the high steep walls of the canyons provide protection from the winter winds and more hours of shade from the summer sun than the open areas along the river. Mobility is of prime importance and the larger canyons appear to facilitate rather than impede movement between the Bofecillos uplands and the lower valleys. Rock shelters provide protection from year-round climatic conditions–cold, wind, rain, and sun. The terraces do not have such well-rounded advantages but provide a larger living area than do the shelters.

It is difficult to attempt to discuss the relationship of the river and canyon sites to one another or to the other area sites, because the entire region has not received complete coverage, and the distribution pattern, though possibly accurate for those sites within the surveyed areas, is not necessarily representative of the uninvestigated regions. The north-south gravel ridges and the mesa tops have received only a brief scan during "spot checking" and the side-tributary canyons have not been investigated at all. Also, the Mexican side of the area has not been surveyed, and it is not reasonable to assume that the Rio Grande was a barrier to the prehistoric inhabitants of the area. With these considerations in mind, some preliminary speculations concerning the possible social interrelationship of sites are presented.

The five river sites located above Colorado Canyon are at approximately one-half to one and one-half mile intervals, while the sites below the canyon are situated with one mile between Site 41PS125 and Site 41PS119 and one-eighth mile separating Site 41PS119 from Site 41PS120. This spacing, along with similarities in the nature of the cultural debris, might imply frequent social interaction. Because of the greater horizontal site extent and greater density of cultural debris exhibited at Site 41PS124, it is feasible to speculate on the possibility of this site as a semi-sedentary occupational "base" camp with the other sites representing smaller, associated limited activity or temporary habitation areas. Because a functional and temporal division of sites could not be discerned from the data collected during this reconnaissance, additional work will be necessary for testing this hypothesis.

Associations between sites located with an individual canyon is equally as difficult to discern. Sites are well spaced throughout the canyons, but accessible to one another by less than a few hours walk. The spacing possibly suggests an attempt to protect the area against over-exploitation, as well as a means of maintaining stable coexistence between man and the fauna of the canyons upon which his subsisdence partially depended. Site size and density of occupational debris are representative of possible reutilization of a preferred area, such as a main camp, while smaller sites represent limited activity areas. This is the same general assumption that was presented for the river sites.

Accessibility of the river and canyon areas to one another and similarity in the physical characteristics of sites suggest that cultural associations and social interactions between the inhabitants of the river and canyon sites existed. The settlement pattern appears to consist of temporary camps along the Rio Grande and the tributary canyons with variation only in site size and specific site function. Unfortunately, very few studies of exploitation and/or settlement systems of aboriginal groups have been conducted. From the published information, the distribution and temporary nature of the Colorado Canyon sites is suggestive of an exploitation and settlement pattern similar to that of the Chiricahua Apache, an historic aboriginal group of the Southwestern United States (Martin and Plog 1973:156). This historic Indian group occupied a transitional, semiarid environment in an upland and valley region which bears similarities to the topographic setting of the Colorado Canyon area. Although the Chiricahua Apaches depended on hunting and gathering for their total subsistence, they practiced casual agriculture which entailed planting seeds and abandoning them throughout most or all of the growing season. They exploited resources from both valley and upland areas, moving in a nomadic manner from camp to camp as warranted by the availability of the resources (Martin and Plog 1973:156-158). A similar system may have been utilized by the aboriginal inhabitants of the study area.

No subsistence and settlement pattern could be found in the available data which might be used as a model for explaining the possible association of the river and canyon sites to the sites located in the Solitario and upper Fresno Creek Canyon (Hudson 1976). However, Martin and Plog (1973:157) state that populations less dependent on agriculture, as the inhabitants of these sites are assumed to have been, tended to hunt and gather primarily in the uplands with the lowlands as secondary exploitation areas. In this case, larger sites with a greater density of cultural debris would be expected to be found in the upland areas with fewer, less dense sites in the lowlands and valleys. The data from the surveys indicate some resemblance with Martin and Plog's proposal (1973:157) but further comparisons during future work will be necessary before a well-founded statement can be made. Due to proximity, sites in Madera Canyon, the easternmost canyon surveyed, and sites in Arroyo Segundo, the westernmost area of the Solitario-Fresno Creek survey, should offer the best information in attempting to compare and formulate associations concerning possible cultural affiliation and/or exchange systems.

No prehistoric ceramic artifacts were observed at any of the Colorado Canyon sites or as isolated surface finds in the general area. This absence of pottery is an intriguing problem. The Polvo Site (Schackleford, 1955) at Redford, Texas still remains as the southeasternmost settlement along the Rio Grande of southwest-influenced ceramic-manufacturing agriculturalists. The Colorado Canyon sites possibly represent temporary camps utilized by Polvo inhabitants for hunting and gathering purposes. However, if this were the case it would be assumed that ceramic vessels would be used for transporting the processed resources back to the main camps, and thus the occurrence of at least a small sample of sherds would be probable. The absence of observed sherds in the area tends to cloud the possibility of such a relationship.

Other areas presented for consideration in the attempt to designate possible culturally and socially related groups are the Big Bend Park and Amistad regions to the east and the central Davis Mountains to the north of this survey area. Because lithic assemblages are of great importance in defining the cultural affiliation and chronology of these areas, and due to the lack of diagnostic lithic artifacts from this survey area, attempted comparisons would be useless. Hopefully, further investigations will produce artifactual material for comparative purposes.

SUMMARY

From the previously presented data we can conclude that continued archeological work is imperative for knowledgeable discussion of the cultural and environmental manifestations of these sites. Only general, speculative assumptions can be given as a summary of the archeology of this small area at this time.

The sites seem to indicate utilization of the majority of available habitable areas along both the Rio Grande and the major tributary canyons, with the selection of other areas based on the number of advantageous conditions and resources offered. Although much variability is evidenced in site size, it is hypothesized that aboriginal populations were represented by small, sociocultural groups organized by clan or kinship. Group size might have varied during different seasons with this variation manifested by cultural indicators at the sites. Basic subsistence appears to have relied on nonspecialized hunting and gathering of local resources, with the possibility of limited agricultural attempts not completely disregarded. This subsistence system is indicative of an Archaic or early Neo-American lifestyle. A preliminary review of all the river and canyon sites seems to indicate cultural interaction, if not affiliation, between these area sites. No pottery was observed which might indicate association with the agricultural ceramicists of the Polvo site or other ceramic sites to the northwest of Redford, Texas, and no lithic artifacts to link them to sites in the Big Bend, Davis Mountains, and Amistad areas. The most valid cultural association suggested is between the Colorado Canyon sites and those sites in the Solitario and Fresno Canyon to the northeast of this survey area.

RECOMMENDATIONS

The lack of conclusive information offered by the analysis of the collected data reaffirms the preliminary nature of this archeological reconnaissance. If the State of Texas purchases this land, it will assume responsibility for executing further research, protecting the resources, and planning and directing the utilization of the area. Recommendations concerning the future of the archeological resources are presented for consideration.

An intensive program of archeological research should be initiated. A comprehensive area survey should be made to insure the collection of the greatest amount of information possible. The survey should entail complete recording of each site, controlled surface collection, and limited subsurface testing where necessary for evaluation of site potential. If the area is to be set aside for public use, provisions for protection of archeological resources must be made. Sites likely to be endangered or destroyed should be reinvestigated and excavated accordingly and the derived data evaluated and presented in a published report. If warranted, sites should be nominated to the National Register of Historic Places. Hopefully, future work will enable us to define the cultural affiliations and chronology, determine a functional classification for sites, provide conclusive evidence of the prehistoric environment and subsistence system, determine settlement patterning, and provide valid evidence for sociocultural relationships with regional sites.

Because sites, particularly rock shelters, manifest obvious surface features and cultural debris, some means of protection for these cultural resources must be found. Methods of protecting the pictographs of Site 41PS114 should be given serious consideration. Education of the public as to the nonrenewable nature of these resources is most important for their future protection. Ultimate protection might demand designation of areas for public use with other areas restricted for use as a natural preserve limited to multidisciplinary scientific research.

Final decisions on the ultimate use of the land should be made only after serious deliberation and evaluation of possible impact. Once the area is opened to public use it will never again return to its natural state. Public facilities (parking lots, rest areas, etc.) would be inevitable, and this creates the necessity for alteration of the landscape and use of the area resources. Previously opened areas, such as Big Bend National Park, should be critically studied in order to determine the future of the Colorado Canyon area.

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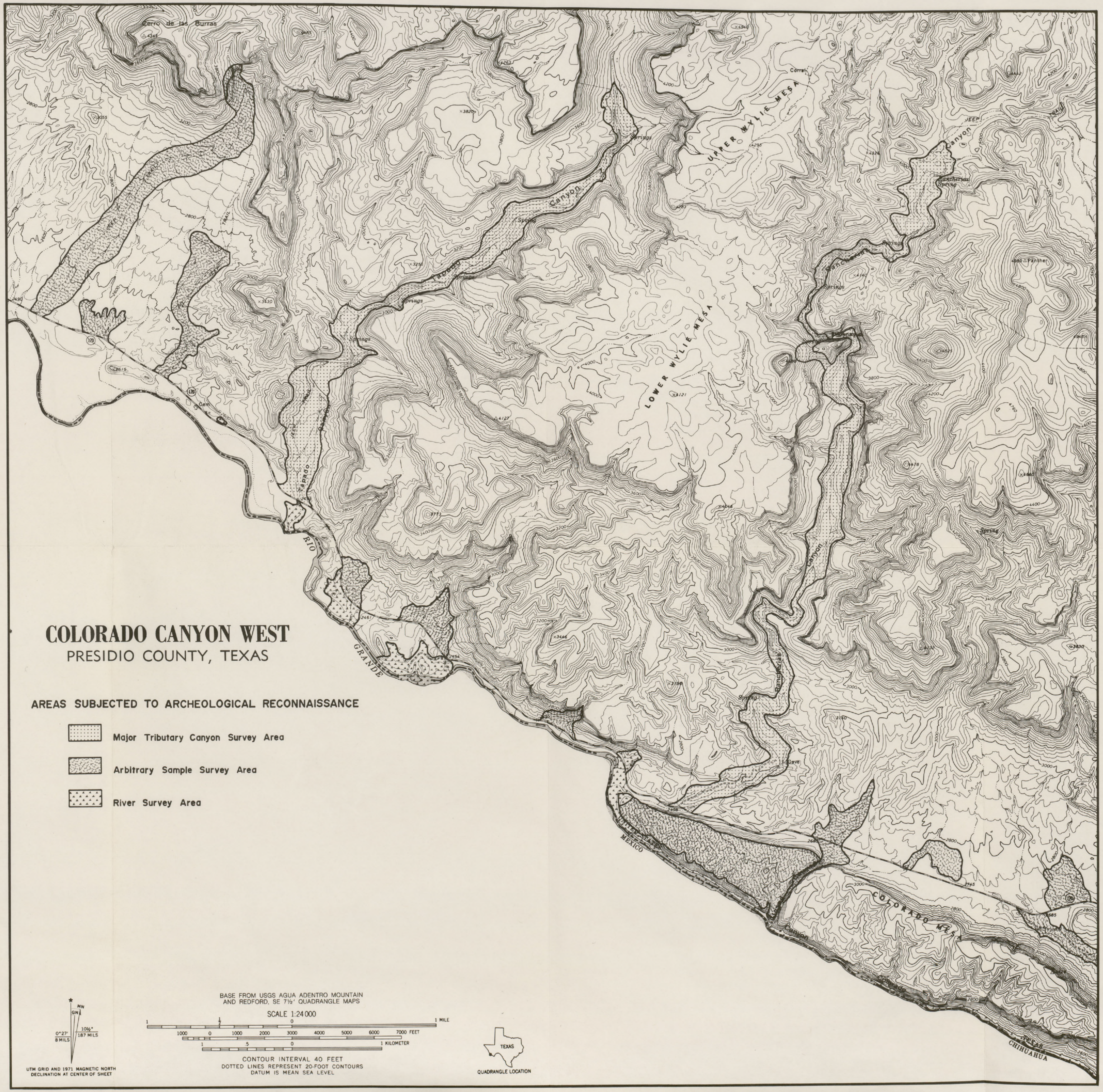
COLORADO CANYON

A NATURAL AREA SURVEY
NO. 11

contains 6 maps

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976



COLORADO CANYON WEST
PRESIDIO COUNTY, TEXAS
AREAS SUBJECTED TO ARCHEOLOGICAL RECONNAISSANCE
Major Tributary Canyon Survey Area
Arbitrary Sample Survey Area
River Survey Area
Cerro de las Burras
Canyon
UPPER WYLIE MESA
LOWER WYLIE MESA
Panther
Spring
Sauceda
Canyon
RIO GRANDE
MEXICO
COLORADO MESA
TEXAS
CHIHUAHUA
BASE FROM USGS AGUA ADENTRO MOUNTAIN
AND REDFORD, SE 7½' QUADRANGLE MAPS
SCALE 1:24 000
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1 KILOMETER
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
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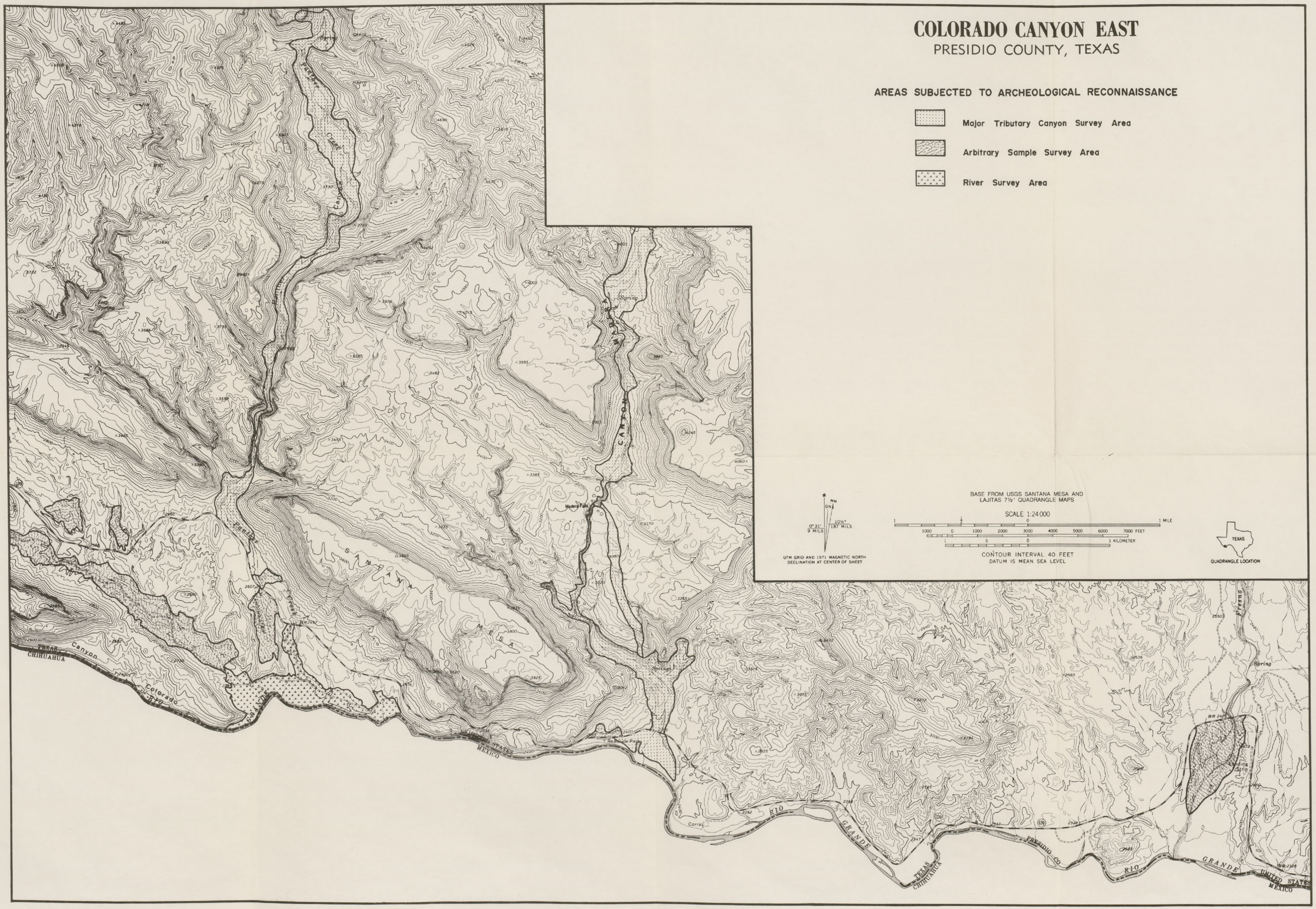
DECLINATION AT CENTER OF SHEET
TEXAS
QUADRANGLE LOCATION



COLORADO CANYON EAST
PRESIDIO COUNTY, TEXAS
AREAS SUBJECTED TO ARCHEOLOGICAL RECONNAISSANCE
Major Tributary Canyon Survey Area
Arbitrary Sample Survey Area
River Survey Area
BASE FROM USGS SANTANA MESA AND LAJITAS 7½' QUADRANGLE MAPS
SCALE 1:24000
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
TEXAS
QUADRANGLE LOCATION
SANTANA MESA
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CHIHUAHUA
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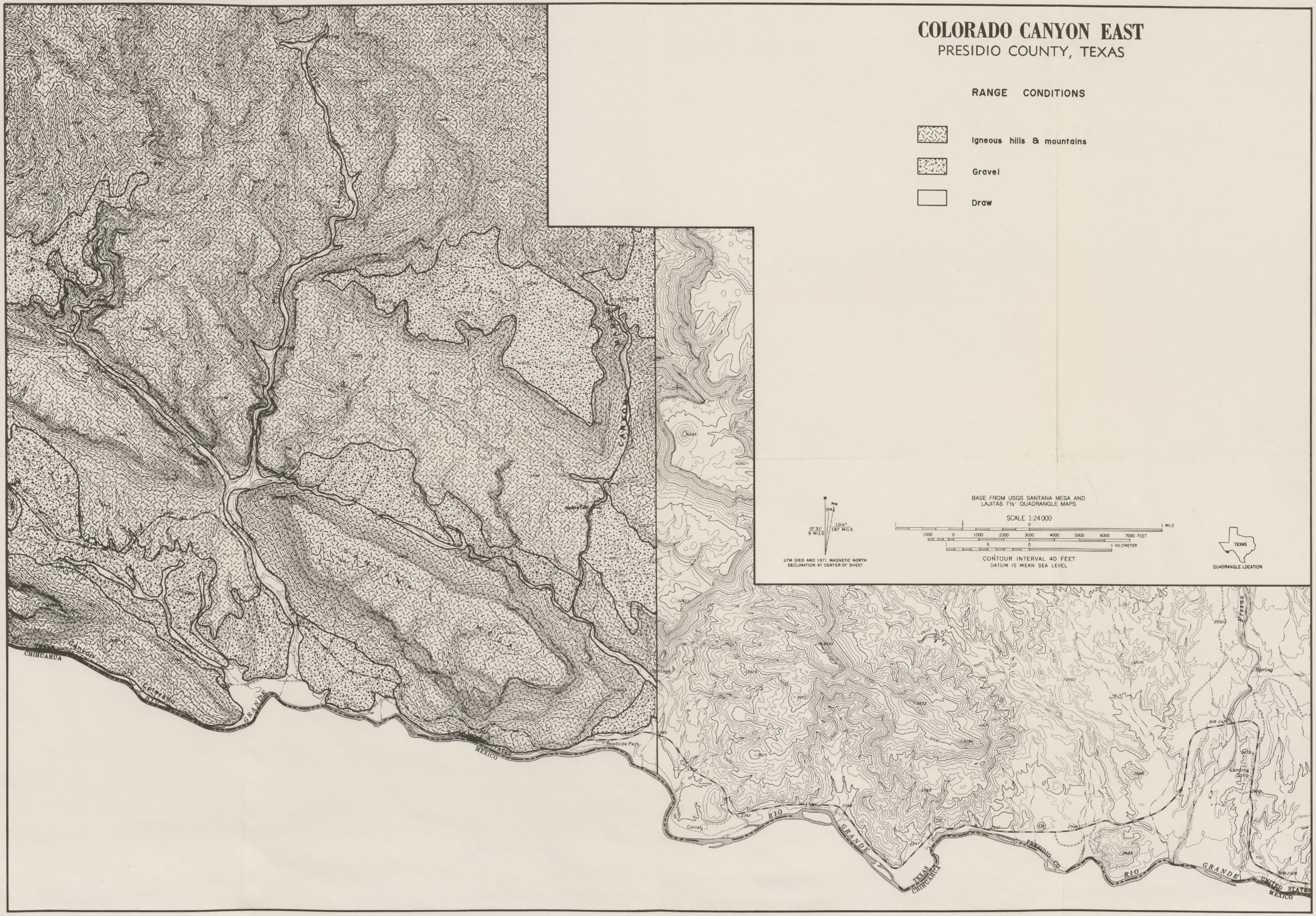
MEXICO
PRESIDIO CO.


COLORADO CANYON EAST
PRESIDIO COUNTY, TEXAS
RANGE CONDITIONS
Igneous hills & mountains
Gravel
Draw
BASE FROM USGS SANTANA MESA AND
LAJITAS 7½' QUADRANGLE MAPS
SCALE 1:24000
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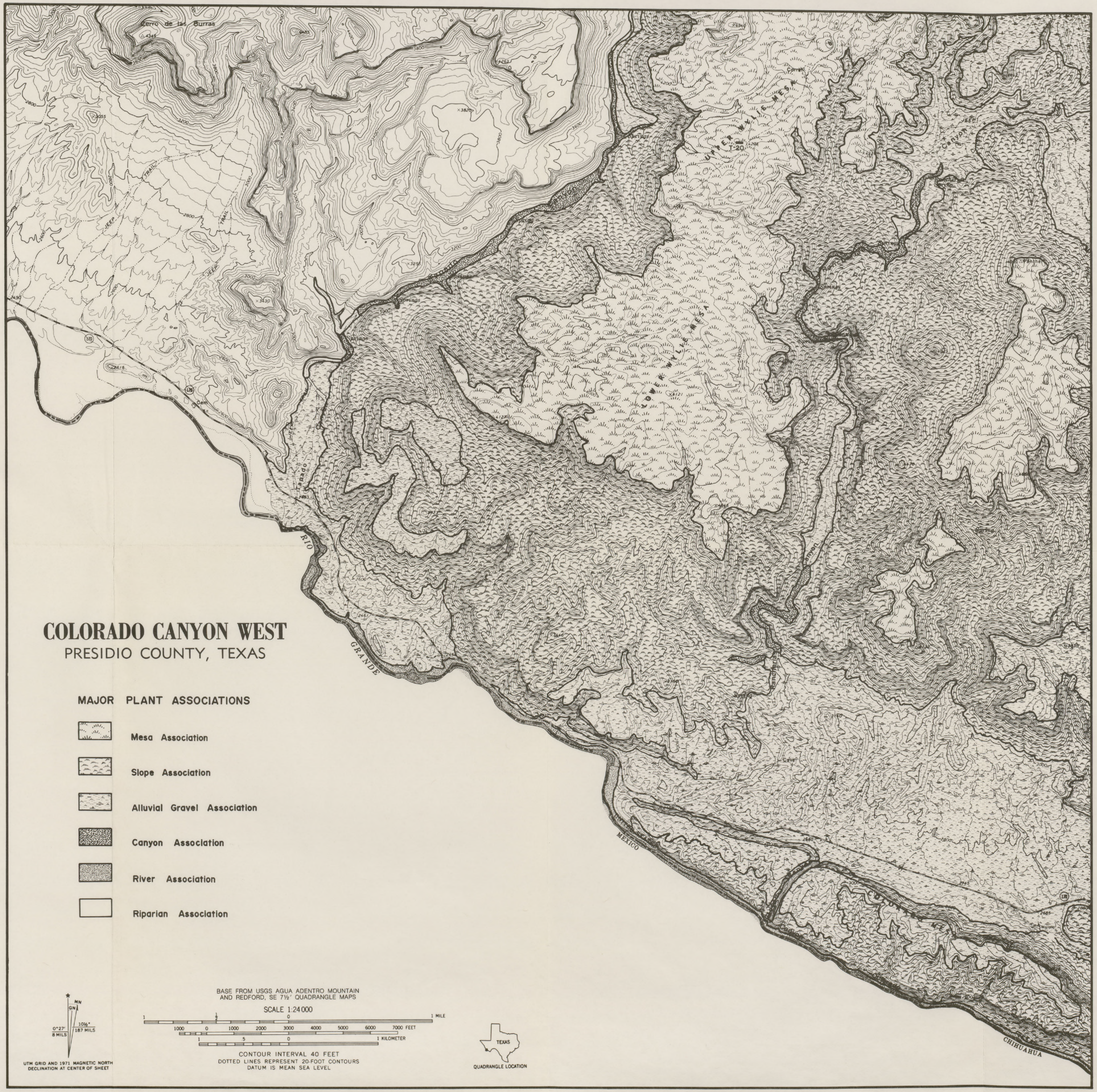
Corral
Spring



COLORADO CANYON WEST
PRESIDIO COUNTY, TEXAS
MAJOR PLANT ASSOCIATIONS
Mesa Association
Slope Association
Alluvial Gravel Association
Canyon Association
River Association
Riparian Association
Cerro de las Burras
RIO
GRANDE
MEXICO
CHIHUAHUA
LOWER WILLIE MESA
UPPER WILLIE MESA
BASE FROM USGS AGUA ADENTRO MOUNTAIN
AND REDFORD, SE 7½′ QUADRANGLE MAPS
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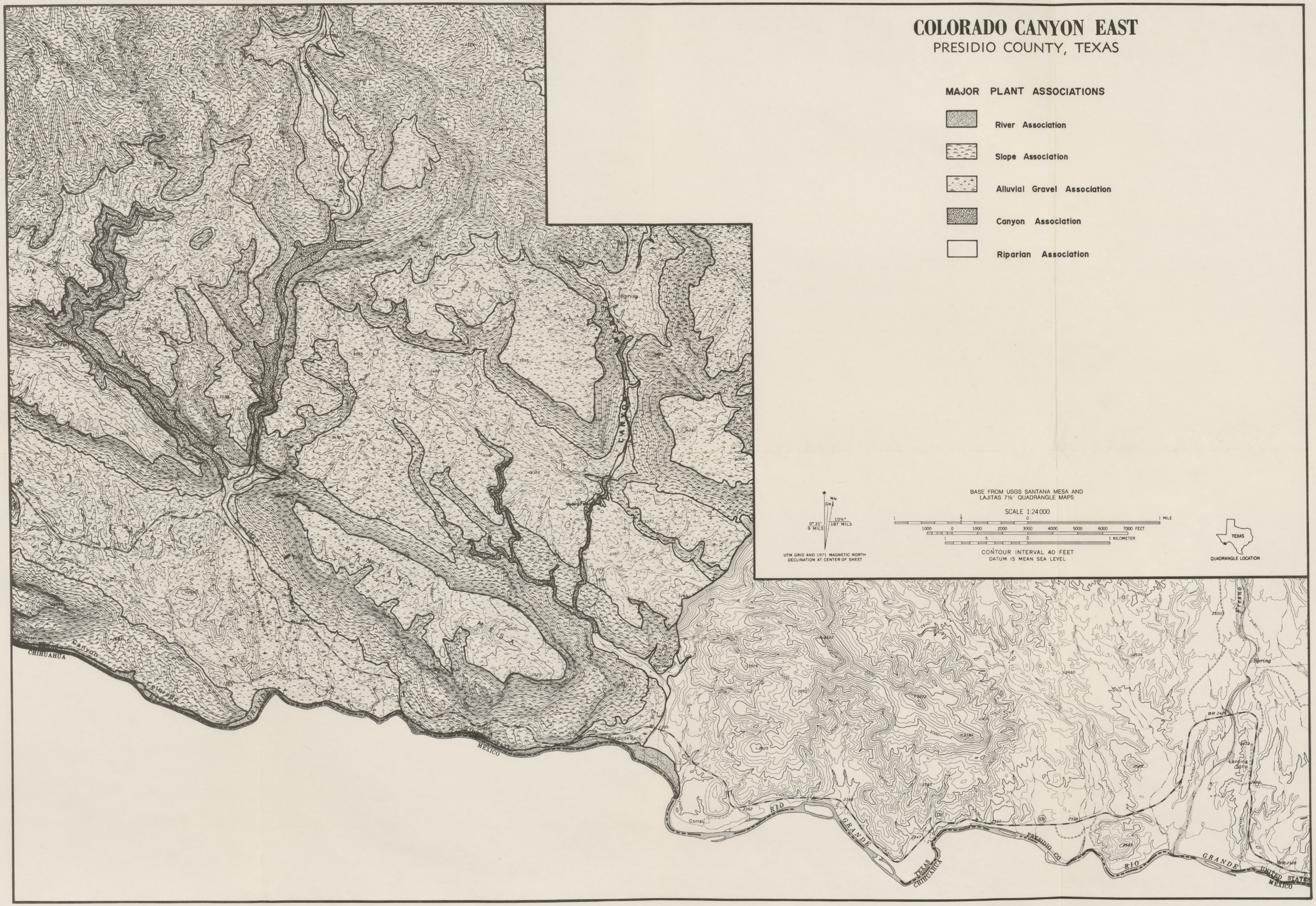

COLORADO CANYON EAST
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River Association
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BASE FROM USGS SANTANA MESA AND LAJITAS 7½′ QUADRANGLE MAPS
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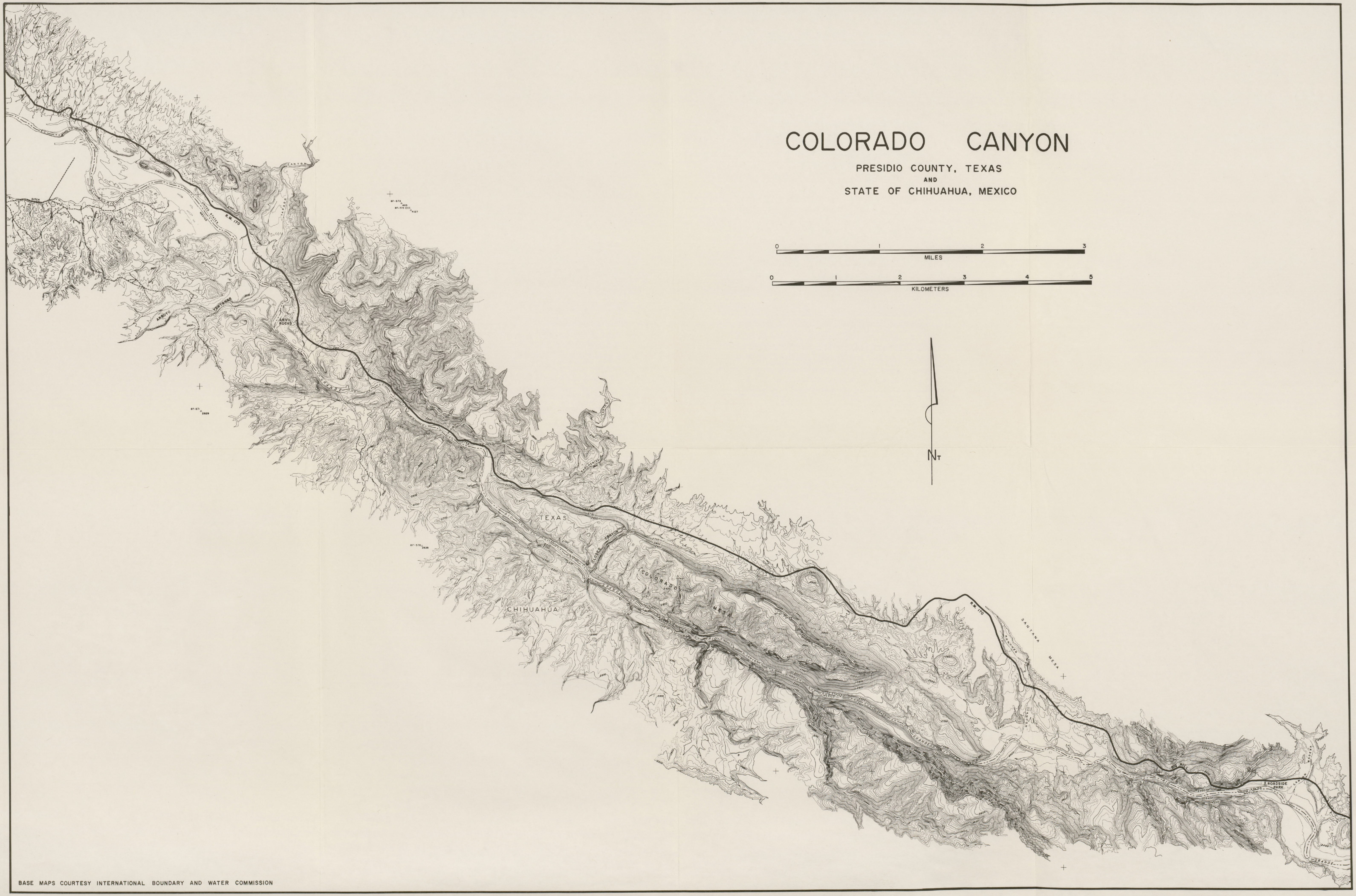
COLORADO CANYON
PRESIDIO COUNTY, TEXAS
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STATE OF CHIHUAHUA, MEXICO
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TEXAS
CHIHUAHUA
COLORADO
MESA
SANTANA MESA
ANVIL ROCKS
ROADSIDE PARK
BASE MAPS COURTESY INTERNATIONAL BOUNDARY AND WATER COMMISSION